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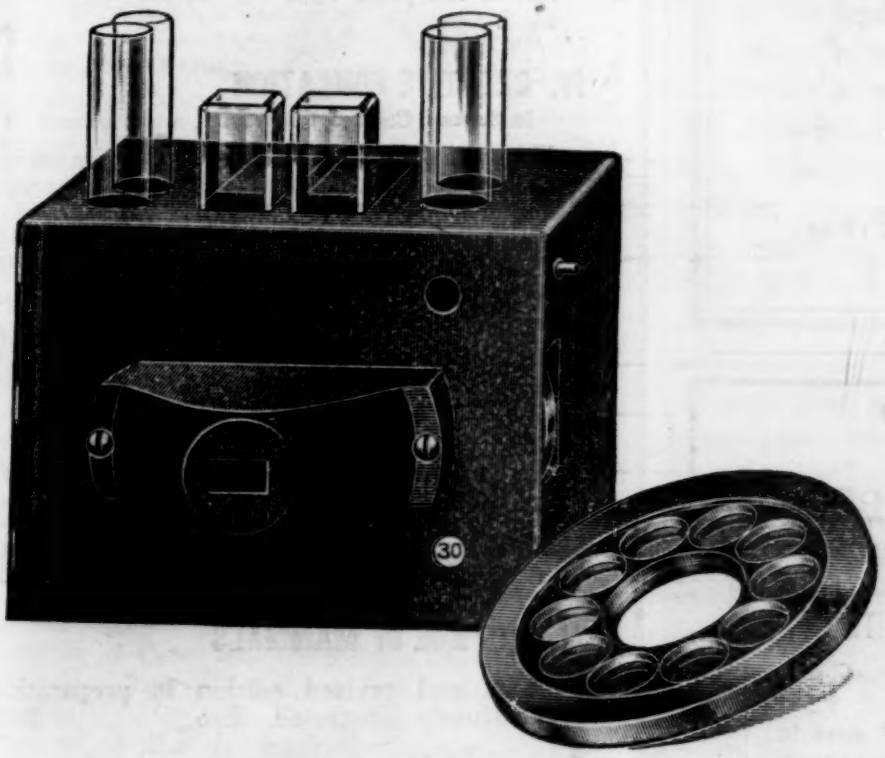

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ORGANIZATION OF SCIENTIFIC RESEARCH IN INDUSTRY[1]

FINDING AND ENCOURAGEMENT OF COMPETENT MEN

TWENTY-FIVE years of doing, finding and encouraging others to do scientific research in industry, and of organizing the machinery for the smooth and effective conduct of such research, have left me with a feeling that so far as this branch of human activity is concerned the problems in essence are not materially different from those met elsewhere. Years ago, in a less mature period of life, I may have thought that the effective industrial research man was a being somewhat different from his fellow workers in adjacent fields. I may have thought that some peculiar slant of mind, some slightly different outlook on life or some special appraisement of relative values branded him with a distinguishing hallmark that designated him unescapably for special treatment and special relationship in the industrial environment.

If such ideas were ever mine, I have long since outgrown them. My present view is that except in those details which are the direct consequence of a particular function, the problem of finding and encouraging competent men in industrial research is in no substantial measure different from the finding and encouragement of competent men in any walk of life. If this conclusion is correct, the subject I have been asked to discuss narrows itself down to a consideration of the things which distinguish achievement in industrial research from achievement elsewhere.

In any discussion of this sort one must have clearly in mind at the outset that which we wish to consider. I take it that we are not here concerned with the finding and encouragement of the rank and file of those who do a fair day's work for a fair day's pay in the field of industrial research, nor even with those who do somewhat more than a fair day's work for a fair day's pay. I take it that we are considering what the title of the subject implies, namely, the finding and encouragement of competent men, that is, men competent in a creative sense or competent in

[1] Symposium before Section M, Engineering, American Association for the Advancement of Science, New York, December 29, 1928.

those characteristics of administrative ability which make them fit leaders of industrial research groups or organizations. It is to these men, relatively few in number, to whom we must look for those substantial results which in the last analysis will be the justification for industrial research as we have come to understand it. Without them the term "industrial research" is merely the designation of a shallow thing of little present and no prospective worth.

The rank and file of the modern industrial research organization are relatively easy to find, though sometimes difficult to get in sufficient numbers. Mistakes in choosing them are not particularly serious to the organization, however unfortunate they may be for the misplaced individual who persists too long in the wrong environment. The reason for this is obvious from the fact that, taken by and large, the work of the rank and file is at best necessarily a work of detail done under guidance of the more experienced. In this respect the situation of the rank and file in an industrial research organization is not different from that of the rank and file in any other group activity, whether concerned with industry, the university or the church.

This does not mean, however, that we are not all anxious to have the best possible material obtainable in the rank and file, or that we are indifferent to the utmost of encouragement and stimulation to its individual members. We want to see each and every one make the most that he or she can out of life. We rejoice at every individual advancement, even though at times that advancement takes the individual out of the organization of which he has hitherto been a part.

Coming now to the finding and encouragement of the group we have designated as "competent," what are the conditions that confront us? In some respects these conditions are easier than those surrounding other activities because they are concerned with narrower fields in which to search. In other respects they are more difficult because of the very narrowness of the field of choice.

I take it for granted that a man is essentially miscast and essentially a transient if he finds himself in a field of endeavor where the primary requisite for success is alien to the thing he most desires. Even if this desire is unrecognized by him at the start it will sooner or later develop, and either wean him away from his environment or leave him a dissatisfied and essentially unproductive member of a fraternity with which he is out of tune.

Put concretely, what I have in mind is that a man driven, let us say, by a zest for personal wealth and the things which personal wealth will buy, is essentially miscast if he embarks in a field which does not lead pretty directly to individual personal wealth. The occasional case of a man capable of turning the opportunities of an otherwise unpromising occupation to the advantage of an aspiration which would normally find its easiest accomplishment elsewhere is no refutation, I think, of this thesis. Wealth resulting directly or indirectly from one's work, on the other hand, may be and frequently is quite different from the desire to accumulate an individual fortune.

Or, take the case of the man whose greatest satisfaction is tied up with his desire to exercise power over his kind. He is in unhappy surroundings, momentarily at least, if perchance he finds himself engaged in an occupation the apex of whose success is, let us say, power over the force of nature.

In both pure science and industrial research the men who succeed will be, for the most part, those men in whom the element of curiosity about nature and her ways is a controlling urge. With similar desires and similar training, the forces which tend to place the individual in the pure science field or that of applied science will be those secondary influences concerned with the allurements of the academic surroundings, the desire to have one's work concretely useful, or some of the thousand and one minor factors of propinquity, heritage, environment or chance.

Except in a minor way, there is no large available reservoir in which we can fish for men of proven competency in industrial research. Here and there we may, if we are so minded, pick out a man who has won his spurs in the field of pure science and transplant him to our industrial research orchard, or we may on occasion avail ourselves of an opportunity to transfer a man of maturity from one part of the industrial research world to another. Neither of these processes is, however, of any considerable value in strengthening industrial research. The first is a questionable procedure, particularly if indulged in freely, since the price paid for a temporary advantage is the almost certain degradation of the ultimate supply of trained men and new fundamental knowledge. The second is a mere shuffling of the cards in the deck and in some cases is ethically objectionable.

To those of us who are concerned with the building up and perpetuation of industrial research groups to function effectively year in and year out, the problem of finding competent men boils down in the last analysis to our ability to find competent *young* men and, having found them, to bring them into the organization, provide them with the facilities and encouragements for growth, and ultimately to make leaders of them. For the most part our search leads always in the same direction, namely, to the institutions of learning and to the parts of those institutions where men are given advanced training in science

Out of the youthful timber which we find here we must make our selection. Occasionally the choice is easy—more often hard. To know and appraise a man well one must live and work with him for a long period. For the most part we who are in search of men do not have this opportunity. We must rely on such casual tests as our experience leads us to think worth applying. We should in the main be able to eliminate those who have inadvertently chosen an uncongenial occupation and who even though temporarily inducted into the industrial research field will not continue there for long. We should likewise be able in many cases to eliminate those who while properly cast in the field of scientific research would nevertheless find the environment of the industrial research laboratory distasteful as compared with the atmosphere of the college or university. Occasionally but not always we may be able to eliminate the precocious but superficially brilliant youth. It is from the remainder, after these eliminations, that we must make our choice. That choice should be entrusted to men of experience and understanding.

In my twenty-five years of association with industrial research I have had occasion personally to select a great many men. In the main I think I have had somewhat more than average success in the selections. Some, however, have proved quite wrong. Looking back over this experience of successes and failures, it seems to me that in the majority of the successes final judgment was based about one third on my personal appraisement and about two thirds on the considered judgment of a baker's dozen or so of men in the academic world who had had a relatively long and intimate opportunity to observe the subject of choice. Per contra, in the majority of cases which were not successes I am inclined to think that too little attention was paid to the experienced judgment of those in the best position to know, or too much dependence was placed on the expressed opinion of those whose judgment I should have distrusted for any one of a number of reasons.

Summed up, therefore, I should say that in attempting to select young men who in later life will be successful in industrial research, a primary requisite is to come to know the wise men in our college, university and technical school faculties whose judgment applied to the young men they have instructed makes them a more efficient sieve than any casual outsider can hope to be. True, they may not be able to tell you that "X" or "Y" is suitable for your particular situation—that is a matter which you alone are in the best position to judge. They should, however, be able to give you substantial advice, not only as to character but as to the reasonable chance that the youthful evidences of ability are the early fruits of a substantial continuing harvest and not merely the exotic flowering of a hot-air plant or the reflections of a casual environment.

In the matter of encouragement there is I think but little to be said. In a general way we of industry can give encouragement which induces young men to choose aright in the selection of their college and university training. More specifically, when competent men come to us we can see to it that their surroundings, the conditions of their association with their fellows, and the tools with which they work, are congenial and adequate. Above all, we must see to it that a just recognition of their achievements is accorded them. While adequate monetary reward in the form of salary or otherwise is a necessary and very important part of the problem of encouragement, it is in many cases, beyond a certain point, less important to peace of mind and continued productivity than are the conditions of environment and of a sympathetic human understanding of things accomplished, of obstacles overcome or of problems to be struggled with.

Neither with respect to the matter of choice nor the problem of encouragement are there in the field of industrial research, more than elsewhere, any hard and fast rules which can be applied with machine-like precision. We are human beings dealing with other and, to a large extent, younger human beings. The constants and variables of our particular equations may differ, but they are still the same equations with which other groups in other fields are struggling to solve like problems. Our success or failure in the selection and encouragement of men in the industrial research field is to a large extent a test of our individual sapiency. If proof be needed that the problem is susceptible of solution in many ways, we have only to look about us to see how widely dissimilar in point of view, experience and method are the men who have unquestionably succeeded in building up effective industrial research organizations in many fields of applied science.

F. B. JEWETT

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ENCOURAGING COMPETENT MEN TO CONTINUE IN RESEARCH

MAN has been researching for at least two hundred thousand years, but only within the last two decades has he heard about organized industrial research. It is therefore fair to say that relatively little is known about the best way of doing it. It is a started experiment, and perhaps people will decide sometime that the present course is a terribly dangerous race

for merely material things and so must be changed. We may sometime settle back in static and dynamic equilibrium, each one busied with his neighbor's laundry. But before this is done, we here expect that competent research men will in general receive pecuniary rewards approaching those of men who merely "sell the stuff." There is a healthy tendency in that direction. However, this talk is not an appeal to the public for higher salaries, but rather an attempt among ourselves for better understanding of what constitutes encouragement.

Industrial research is an expression of the advanced and advancing state of American minds. This is true not only of the industries but also of the research men themselves. Nothing seems established except this forward movement. It is what Kettering, of General Motors, might call a "perfectly satisfactory unsatisfied, but not dissatisfied state."

The obvious way to encourage is by encouragement, but encouragement has never been standardized. Coin is a token and performs useful functions, and salaries of research men will continue to rise. The accumulated research of an inventor's lifetime used to be sold for what it would bring under a forced sale. Novel processes and new ideas were produced by millions (there are nearly two million American patents), but not one per cent. of the hard-working inventors were ever rewarded at all. They worked under heartbreaking disadvantages and carried the entire risk of their ventures. The public would have been well justified in sharing the risk with competent workers. Later it seemed more promising to grubstake the inventor, and this was quite generally done. Many lines of industry were built about a single experimenter. The more recent scheme is to stake groups of trained and selected investigators and combine their work so that new results may be continuous. This is now a tested development. It is easy to see its advantages. On the whole, it costs the public less and produces better results than the shiftless way of rewarding the occasional inventor who ripened his product on the day the market was exactly ready, while declining even to feed the poor fellow who was far-seeing and got ahead of the procession.

But the unlimited use of coin alone does not guarantee satisfaction anywhere, and we are thus led from the subject of salary, in which no one is expert, to the conclusion that the adequate compensation for encouragement to continue research must include those tokens of appreciation which other creative people generally desire. This is a strong survival principle for a race. Publication in some form to bring recognition by one's peers is the nearest equivalent to the artistic painting, the beautiful poem, the enduring sculpture and the splendid architecture of other creators. The most altruistic and far-seeing leaders realize the importance of this encouragement, and even those who have never analyzed it instinctively feel its value.

Another token of research appreciation, strange as it may seem, is further opportunity for more and better work. The research man must progress. In the industry this means improved facilities, new apparatus and enlarged activity of all kinds. Every good research man wants to work with new and improved tools, and this includes everything, from freedom from interruption to added assistants and floor space. If this encouragement is criticized as not being a token of appreciation, I can only say that it is a weighty matter of experience.

WILLIS R. WHITNEY
RESEARCH LABORATORIES,
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IS RESEARCH A GAMBLE?

RESEARCH is good business when run on a business basis. Scientific study of an industry from every angle will pay for itself in the new knowledge gained. If new products or new processes come out of such research, then is the time when one may expect to begin to spend money. The development that must follow research if successful production is to come later may cost many times as much as the original research, with a chance that all may be lost. A good research business man takes no blind "fliers," but first feels his way, making his mistakes on a small scale rather than later on a large, manufacturing scale. Thus is the chance for failure reduced to a minimum, provided resources are not exhausted by too large a venture or too many new development projects at one time. Industry must engage in research or fall behind in the race to-day. Intelligent persistent research and development is bound to win in the long run. If all is not staked on one idea and a few experiments, the law of averages will remove most of the gamble. The successes may not be along the lines of first endeavor; they may be even greater than at first thought possible; but they must at least earn enough over the returns from standardized, competitive industry to warrant the risks and the expensive delays incident to all industrial development.

L. V. REDMAN

RESEARCH IN THE ENGINEERING COLLEGES[1]

THERE are significant differences of national policy concerning the character of the higher schools of engineering and their function in the social order

[1] Read before the Section of Engineering, American Association for the Advancement of Science, New York, December 29, 1928.

which can be understood only in the light of their historical backgrounds. Fifty years ago Dr. C. O. Thompson, the first president of Rose Polytechnic Institute, observed from his studies of the engineering schools of Europe that there had been little change in their essential character after the first ten years of their existence. It appears that the character of institutions, like that of persons, is largely conditioned by heredity and early nurture. Later growth is more often a maturing than a formative process. Those who know the American colleges of engineering well are aware of the grip of historical tradition which is always more of a ruling force in institutions directed by legislative action, such as colleges, than in industry and other institutions where executive authority prevails.

It may be profitable to spend a moment in a brief review of our national types. Education for the technical professions had its origins in France. The early schools developed within the technical services of the state. Their aims and spirit were exclusively professional. Later the École Polytechnique was created to assure a high intellectual formation in advance of professional training proper. These early institutions had no organic connection with the university system. Their exclusive aim was to provide a *corps d'élite* of engineers for the state and industry. They were strictly teaching institutions, staffed by practitioners and savants whose major interests were elsewhere. The character of the professional teaching was notably high, and many of the teachers were men of great creative genius, but their creative activities were largely done off the premises. The influence of the so-called *grandes écoles* of Paris was world wide, and not least in America. In France itself they fixed a norm of technical education which is still dominant. Their professional discipline is notably thorough, but the professors give only a part-time service, graduate students are unknown and research is largely a stranger to their precincts. A new type of organization has been growing up in the past thirty years in a group of *instituts techniques* in the provincial universities. While they have been deeply influenced by the strict professional traditions of the *grandes écoles* of Paris, their attachment to the faculties of science has worked in another direction. They have a fair proportion of full-time professors and an active research spirit. Graduate students in French technical schools are rare, almost to non-existence. Provisions of the award of the doctorate in engineering for researches in the universities have only recently come into effect. In general, the place of research in French engineering schools is incidental, secondary and indirect. France has almost the entire distance to travel in making it a primary force.

The historical genius of British technical education must be sought in a welfare movement for workingmen. Industry, scientific inquiry, higher learning and professional training grew up in separate compartments of British life, and the barriers have not yet been completely leveled. The pioneers of British engineering and industry were workingmen and it was assumed that a succession would arise by sheer force of native ability, helped on by incidental scientific instruction in evening schools. This idea dominated by far the greater part of British technical education until nearly the end of the last century. The idea of creating a highly trained professional personnel to apply science to industry was largely alien to British thinking in that period. Meanwhile the engineering schools in the university system struggled along against odds of hostility and neglect. The last forty years have greatly changed this situation; industrial competition, chiefly with Germany and America, and the recent war, awakened Great Britain to the greater effectiveness of professional scientific effort. University schools of engineering have been greatly strengthened. The fact that there are two quite distinct types of technical schools has led to a fairly definite division of function. The so-called technical institutions, heirs to the early welfare movement for workmen and controlled by local education authorities, serve the local population and industries in a most direct manner through their part-time and evening instruction, and provide fully nine tenths of the technical recruitment. The university schools of engineering, on the other hand, devote themselves to general and fundamental, rather than local and immediate needs. They are small units, with an average of less than three hundred students. There are few full professors, and they are selected for their scholarly distinction rather than their activity as practitioners. The possibilities of specialization are very limited and the schools work at fundamental things both from choice and from necessity. Research has taken a firm rootage in this soil and found it fertile. The crop is choice, rather than large. Much of the research in progress is less specialized and in that sense less advanced than that which abounds in Germany. There is little direct cooperation with industries, but a large share in the work is initiated by national agencies, and it aims to be fundamental in the highest degree. The universities are not first-aid stations for British industry, nor are they convenient service stations for routine tests. There is little or no confusion about the aims and nature of research.

Germany is the land of technical research, *par excellence*. The resurgence of the German states after the Napoleonic era was the historical miracle of the nineteenth century. There has probably been no other historical movement in which technical education and research have had so large an influence. Poorly endowed with natural resources and lacking capital for the upbuilding of industry, the German states turned to the creation of scientific knowledge and skill as the means of their economic salvation. In all the history of German technical education there appears the hand of statecraft, deliberately reshaping old agricultural regions into the modern industrial empire. The technical sciences began to gain a precarious place in the German universities late in the eighteenth century. Once the issue was clearly defined, the new disciplines were thrown out, as alien to the genius of abstract and disinterested learning. Statesmen came to their aid, Count Von Gerstner in Bohemia, Nebenius in Baden, Beuth in Prussia. It was necessary to begin with trade schools, then to build up a system of secondary education based on modern studies, and gradually to raise the status of a chosen group of polytechnic schools to the level of complete equality with the universities. This process occupied the whole of the last century. In the last half of the period the attaining of a university status became a major issue, and the form of university organization and work became a strong molding influence on the *technische Hochschulen*. The *Verein Deutscher Ingenieure* put the whole weight of its influence behind the movement. To this end it encouraged a complete separation of the higher, middle and lower technical schools, aided in the upbuilding of the *Realschulen*, raised funds to finance higher researches, drew the support of the industries to the *Hochschulen* and supported their demands for the right to award the doctorate. At the close of the century the equality of the *technische Hochschulen* and the universities was formally recognized by imperial authority. The effect had been to make the *Hochschulen* teaching institutions in a comparatively secondary sense, and to make their function the advancement of technical science and art. German industry was quick to follow the lead of the state and the profession in supporting the technical universities as the chief centers of creative effort. A brilliant example was set by the Krupp interests, who established the Kaiser Wilhelm Institute of metallurgical research at the *Hochschule* at Aachen, at a cost of over $400,000. Many examples could be cited of the policy of German industries of placing the ablest researchers in professorships and of giving them resources for creative work rather than drawing them away to more sequestered work under industrial auspices. Furthermore the policy has been quite consistently pursued of concentrating resources and support for research on selected men and institutions rather than scattering them indiscriminately. In addition to the institute of metallurgy at Aachen, prominent examples are to be found in Professor Rhebock's laboratory of hydraulic construction at Karlsruhe, Professor Becker's automative institute at Charlottenburg, Professor Nagel's center for research on piston engines at Dresden, the unique laboratory of X-ray technique at Stuttgart, Professor Knoblanch's Institute of Heat Physics at Munich, the laboratory for high-tension research at Darmstadt, the laboratories of machine tool technology at Hanover and Charlottenburg, and the institutes of psychotechnics presided over by Professor Möde at Charlottenburg and Professor Sachsenberg at Dresden. Statistics are not obtainable, but the ratio of doctor candidates to undergraduates in Germany appears to be quite as high as the ratio of all graduate students to undergraduates in American engineering schools, and as few American graduate students carry their studies beyond the level of the *Diplom-ingenieur* in Germany, the contrast is even greater than the ratio indicates. German technical universities are so large and their organization is so highly ramified that opportunity is created for a high degree of specialization. No doubt solutions are found for many more specific problems in consequence of this specialization, but it is not yet possible to say whether the ultimate contributions to progress are relatively greater than under the unspecialized conditions of Great Britain. The present degree of activity in Germany bears out the slogan of one of the German technical societies, *Die Technik ist Deutschlands wirtschaftliches Schichsal*—technical science is Germany's economic destiny.

Engineering education in the United States is an outgrowth of a popular movement early in the last century to promote "the application of science to the common purposes of life." There was no thought at the outset of creating any formal discipline for the profession of engineering. The aim was to give farmers and mechanics such a scientific education as would enable them to become skilful in their professions. Rensselaer had scarcely begun its pioneer work as a school of applied science when the advent of the railroad opened a new chapter in the history of American engineering. The engineers of the earlier decades, a scattered group of land surveyors, builders of roads, bridges and canals, and practical constructors of machinery, had been largely self-taught; with the railroad came a demand for engi-

neers with a greater mastery of the scientific resources of the art. There was no existing foundation for a scheme of training by pupilage as in England, and the engineering school arose from simple necessity. The effort to apply science to the common purposes of life passed rapidly into the special form of a professional discipline for engineers. As there were no models in the English-speaking world, they were borrowed from France; with them came the conception of an engineering school as almost exclusively a teaching institution, with a strict disciplinary régime of work. The existing scheme of higher education was of a collegiate rather than a university character. Original scientific inquiry was uncommon. The scheme of engineering education was readily assimilated into the newly developing university system without changing its original conception that its function was to teach that art rather than to create it. For a long period the engineering schools had to face the charge of impracticality from the engineering profession and the industries. The traditions carried over from pioneer days, constantly reinforced by British influence and example, tended to emphasize the gap between theory and practice, to the mild disparagement of the former. The schools turned their effort toward making their training as practicable as possible. Shops and laboratories were introduced which simulated industrial practices. Professors sought to gain recognition of their competency by engaging in collateral practice. The teachers had practically no fundamental training beyond the four-year undergraduate course. American authorship was largely a process of compiling and editing. To get hard work out of their students teachers of engineering worked harder than their academic colleagues in the same proportion. There were here and there inquiring minds which attacked original problems out of native curiosity, but with little encouragement from the engineering profession and the industries and not much more from the educational authorities.

With the development of the field of electrical engineering in the eighties, followed by chemical engineering in the nineties, and with the gradual infiltration into American schools of men trained in Germany, engineering education began to swing away from its effort to be practical to an effort to become scientific. Many of the professors of these new branches had not been trained as engineers, but as physicists and chemists. Their assimilation to engineering enriched and fertilized it with a new scientific spirit. A bond of understanding sprang up between the schools and the new industries which traced a direct descent from scientific research and technique, whereby the employer took all the responsibility for the practical training of the graduate, and left the school free to devote all its energies to his scientific formation. Conditions began to be favorable to research in engineering colleges about 1900. Previous to that time there had been few men in the engineering colleges who had either the interest or the qualifications to pursue it, and the physical facilities had been planned with little regard to it. Meanwhile the tradition had been seventy years in the building that teaching is the chief, almost sole business of the college, that only practical experience and professional reading were needed to qualify the teacher beyond his own undergraduate training, and that collateral practice had the first claim on the spare time of the engineering professor. Research activity gained headway slowly against the inertia of this tradition. Accelerating forces from the state, the engineering profession and the industries, so marked in Germany, were conspicuously lacking. The movement had scarcely gotten under way when American industry waked up to the potency of scientific research as a competitive weapon. Great industrial laboratories arose and the world was scoured for men to man them. Industry had apparently little compunction in drawing the most promising investigators away from the colleges for its own private needs. Considering the limitations under which research in engineering colleges must be conducted there can be no doubt that the productivity of the individuals concerned was greatly increased through the transfer. The seriousness of the matter arose from cutting off the potential supply at its source.

Since the turn of the century the growth of research and quasi-research activities in the engineering colleges has been marked, yet in comparison with the growth of research under industrial auspices it seems that the colleges have relatively lost ground. A fairly complete survey of research activities in engineering colleges made in 1924–25, showed that fifty-eight, or about 40 per cent., had organized arrangements for research, at least on paper. Included in this number were forty-one institutions which have organized plans through which the services of the engineering staff are made available in consulting capacities to industries, public service utilities and others. If we include all institutions where research is fostered on a purely individual basis, the total rises to 110, or about 70 per cent. of the whole group. The total expenditures of the organized research departments in 1924–25 were close to $1,500,000. Of such expenditures, approximately 11 per cent. represented direct appropriations for engineering research by the several states, 40 per cent. funds allotted by

the colleges from their general funds and 49 per cent. funds derived from outside sources, principally from public professional and industrial organizations. About 70 per cent. of this expenditure was made by nine institutions. At least thirty-four institutions reported full-time research staffs, with a total of between 250 and 300 men so engaged. To this number may be added 350 more who rendered part-time research service for definite compensation and about 200 who gave part-time service without special compensation. The numbers engaged on an individual basis can not be estimated.

These totals seem impressive. Their chief value is that of an index. It must be remembered, however, that in the same year two corporations in the electrical industry both spent more than double the total outlay of the engineering colleges on research activities and that at least two in other industries spent more than this total. Recent data on the research expenditures of industrial concerns, collected by the Division of Industrial and Engineering Research of the National Research Council show that at least six corporations are spending upwards of $1,000,000 per annum on research apart from all normal production. Returns from 800 concerns indicate an average outlay in 1927 of $44,500 for these purposes, or 1.3 per cent. of their invested capital. This amount represents a gain of 90 per cent. over the preceding year. Engineering colleges are spending an average of $10,000 apiece for like purposes. Furthermore, it would be very illuminating, if it were possible, to classify the expenditures of the colleges under such heads as actual research for fundamental knowledge, first-aid problems for industry, routine engineering testing, and what may be called quasi-scientific puttering. Confessedly the amount of real 24-carat research would be relatively small, for the reason that few teachers of engineering are capable of doing it or directing it. But then, the American attitude toward language is notoriously easy-going and we use the "word" research to mean so many things that we have no word left to mean "research."

In view of the contrast between the research activities of the colleges and those of big business, it is safe to assume that corporations at this end of the scale are not going to turn to the engineering colleges to get their fundamental problems solved. For one simple reason, they can not wait long enough. Furthermore, big business has discovered the publicity values of research. Big business can probably be induced to invest money in organized research in engineering colleges only on the plea that such activity is necessary in order to maintain the needful setting and staff for training the grade of researchers and engineers that big business requires. Industry is likely to reply that many of their most productive researchers are drawn from departments of pure science. In any case fundamental scientific research rather than engineering investigation seems likely to get the financial assistance from the source, and it will probably be disbursed through some intermediary or clearing-house instead of passing directly to individual colleges and professors. The campaign of the National Academy of Sciences for a national research endowment is working on this principle.

At the opposite end of the scale from big business are the innumerable small units of industry which live from balance sheet to balance sheet, with no consciousness of research needs and little margin for the support of such activities. When a small industry meets some acute problem outside the scope of its normal routine and staff, a college professor or laboratory may be a good place to turn for first aid, but this is scarcely research. Yet it is probably to industries in small units that colleges must look for resources to build up their research work.

Many of these smaller units of industry are concerned with the traditional arts rather than the applications of modern science. They are likely to remain deaf to any appeal to support research for the sake of repaying their debt to science or for the sake of maintaining a wide margin between pure knowledge and practical invention. It is just these industries, however, which are most apt to be handicapped by the decline of sporadic invention and likely to profit relatively most from an adequate program of research. Support for such investigation is not to be expected from the single units of such industries, but their state and national trade associations are the natural agencies to foster such activities. There are attractive possibilities of dividends in the form of better methods, economies and more exact control of the present state of the art. Research looking in advance of the present art is a form of mutual insurance covering the risks of supersession or revolutionary changes in the art.

A recent report of the Babson Statistical Organization announced that an English factory was testing out the production of a flexible, colorless, resilient non-inflammable glass of organic origin. It went on to say:

> The point of this letter, however, is not only about glass. This is but one of numerous far-reaching discoveries which have recently been reported. We believe that business is entering an era of the most rapid and revolutionary changes in the chemistry and physics of manufacturing. To those who are quickest in taking advantage of such discoveries they present unlimited oppo-

tunities, but the manufacturer, merchant or investor who is asleep to these changes will be hurt.

The time has passed when advertising alone will get sales. The two best salesmen to-day are a "better product" and a "cheaper way of making it." Research opens the way to both. Furthermore, since the most deadly competition is not between concerns, but between industries, we urge clients to combine their energies with others in the same line of business. This saves duplication of efforts, leads to maximum results and keeps you best informed about all important developments. Make use of the help which the United States Bureau of Standards at Washington stands ready to give you, and also that of other technical organizations of high standing. Cease worrying about gaining the temporary advantage of exclusive patents, and combine your resources in the way that will do most to permanently help your industry.

(It is significant that the occasion which brought the above report to the writer's desk was a request from its authors for a complete list of the engineering colleges with facilities for organized research in cooperation with industry.) The writer is strongly of the opinion that trade and industrial associations offer by far the most promising agencies through which to promote industrial cooperation with the colleges in engineering research. The support of research by individual corporations is likely to be sporadic, while trade associations can effectively maintain a continuing relation. The results of work supported by individual corporations are apt not to be widely disseminated or used. A good deal of such support is frankly on a courtesy basis, without a vital interest in its effectiveness or utilization, and with little genuine collaboration between the college and the industry.

A trade association, administering its funds in trust for its constituency and genuinely concerned to show a good return for the investment, provides an excellent medium for the joint shaping of research projects and a widely ramified channel through which to disseminate results. It would seem that the most fruitful result may be expected when a trade association concentrates its cooperative program at a single college, or at a small group of institutions at most. Such work ought not to be located on a courtesy basis or split up on a political basis, but should seek to capitalize distinctive advantages of men, plant and environment. There is a definite loss when such resources are spread over many institutions as a fairly ineffectual mist, when they might be concentrated into a fairly powerful stream. In this respect the European situation is far better ordered than our own. The policy of concentrating resources abroad has led to the upbuilding of a group of notable and distinctive research centers which are the principal factor in attracting and holding to educational and research work the outstanding authorities in the several fields. The result has been to give the several institutions an individuality quite unknown among us.

The writer does not feel that the colleges can rest their case for industrial backing for their research programs on the needs of the colleges, or an assumed sense of obligation on the part of industry to see that the colleges obtain the men, money and facilities needed to do their best work. The industries recognize these obligations rather vaguely, and when confronted by the competing pleas of 100 to 150 institutions are justified in feeling rather helpless. The Babson report, however, speaks in the tongue which industry understands and to which it responds.

The work being done at Cincinnati in cooperation with the tanners' and the lithographers' national organizations, the power brake studies at Purdue in cooperation with the American Railway Association, the studies in warm air heating and ventilating at Illinois and the great project of the Portland Cement Association in association with Lewis Institute are worthy examples of adequately supported, nationally backed and effectively concentrated research programs, involving real collaboration between colleges and industries and leading to results of great significance and value.

The backwardness of research in our engineering colleges is probably due less to lack of money than to a shortage of competent research workers. Universities and colleges are the only agencies whose special purpose it is to train such men. The great industrial laboratories do much to further the education of their personnel, yet frankly admit their complete dependence on the universities for basic training. The engineering colleges are under a heavy burden of quantity production for the everyday needs of industry, and industry is in active competition for the more promising output of the colleges. The inducement to enter active employment at the end of the undergraduate period is very great. It is only rarely that men of creative ability have had the opportunity to test and appraise it at this stage. Between the solicitation of employing industries and the natural desire to try one's powers, we must expect most of the young men who might become productive researchers to pass into industry at this stage. The problem is to rediscover them and get them back into graduate schools after a reasonable period of orientation.

The opportunities in the field of engineering research must be kept more prominently before the student in his undergraduate years. This is the duty of both the engineering schools and the technical

industries. Industry needs to recognize its own interest in selling research to a selected few young men, especially among its own employees. Industry needs to send selected men, of clearly indicated ability, back to the graduate schools for further preparation. Both the industries and the organized profession have a duty to make it possible for men of high creative abilities to remain in professorships without undue sacrifice of financial and professional opportunity. American schools of engineering enjoy an unparalleled freedom from outside regulation, but suffer from being left to fend for themselves in the face of conditions such as these. As a representative of the schools, the speaker yields to none in the frank criticism of their defects, but he wishes to assert that the engineering profession and the technical industries have received as much as they have deserved at the hands of the colleges, and even more. Without a heightened sense of responsibility on the part of these bodies and a more effective collaboration between them and the schools, there is little prospect that the defects will be mended.

W. E. WICKENDEN

THE DOCTOR OF PHILOSOPHY AND HIS BUSINESS[1]

IN the few minutes at my disposal let me offer some observations on two topics: (I) *The business of making a doctor,* and (II) *The doctor's business after he is made.*

I

And let us observe that the business of making doctors is one of the major industries of our country, a flourishing business. It is worth noticing that in our 576 colleges and universities the value of plant—that is, the value of buildings and grounds, of libraries, laboratories and material equipment—stands at over two billion dollars, and the annual budget for maintaining graduate education is well over $350,000,000. In these half a thousand institutions, over 150,000 graduate students are under discipline, and about 20,000 graduate degrees are awarded each year.

But this great industry is a young one in this country. Yale University, one of our oldest, conferred its first Ph.D. in 1861, and its list of awards at the present moment stands at 1,374.[2] Our own university, one of the youngest, has given, up to the close of the present academic year, 2,134 Ph.D degrees[3]—and all these since I first came as a student to the campus.

[1] Address at the annual luncheon of the Association of Doctors of Philosophy of the University of Chicago.

[2] *School and Society,* June 2, 1928, page 656.

[3] F. J. Gurney, Recorder, University of Chicago.

Not only is this business of making Ph.D.'s one of the major industries; it begins to look as though we were taking on the airs of mass production. But our task, though expressing itself in large figures, is not so simple as a major *commercial* industry. Our program can be stated as simply as the engineer states the business of making automobiles. In an automobile factory there must be: (*a*) an establishment of standards; (*b*) the machining of raw material into finished form, and (*c*) the grading of product.

But the engineer's problem is simple. The raw materials are uniform in quality. One bar of steel is like the next bar of steel. And though standards of accuracy read like fiction—the dimensions of shafts and bearings, for example, must be true within a tolerance of error of 1/4000 of an inch—there is no serious problem in obtaining uniformity of product.

Our business, the business of the staff, is likewise the establishment of standards and the grading of product—but our problem is not at all easy. Our material—men and women—is far from uniform. Individuals vary widely:

(*a*) In native ability. The Lord did not make them equal in any way. There are geniuses, and mediocrities. And the genius is usually a lopsided individual. He may be quite as marked in deficiencies as he is in excellences, when he is brought up before any set of standards.

(*b*) They may vary widely in preparation and training for the work we have to offer. Often their training has been haphazard and incomplete.

(*c*) They will vary in their response to discipline. Some are young and flexible, others have come late to their advanced work, and in some people the intellectual skeleton begins early to ossify.

And so, although we may establish ideal standards of accuracy, of competence and of refinement, it is hopeless to expect equality. We may not expect it in either rate of growth or in performance or in ultimate power.

To get this complicated raw product milled into a quality which may some day bear the label Ph.D. the seminar is established, and before the seminar the candidate brings a part of his prepared work to be criticized by the entire group. But good as this discipline may be, it is time consuming, and in a large group the individual candidate has a slender chance of having his own particular shortcomings brought home to him for elimination or amelioration. Individuals can not be ground effectively *en masse.* They require *individual* attention.

An eminent professor in Columbia University told me some years ago that he had twenty-seven candidates for the doctor's degree working under his sole supervision at one time. That is "mass production"

with a vengeance. Frankly, it can't be done. There are not hours enough in the working day to do it, if it is done individually, as it should be done. Almost up to the present moment, the administration has expected an instructor to do full work in class instruction and to take on the special training of Ph.D. candidates on the side, extra, without credit and without pay. That is an evil condition, and it must be remedied before we can do our whole duty by our graduate students.

The finished product in a Ph.D. requires infinite pains and endless hours on the part of the instructor as well as the student. The personal conference is invaluable. It is the one thing which counts. An instructor often spends more hours on one individual than in lecture or recitation work on an entire class.

And it is this personal contact with the teacher which means most to the student. Each one of us can recall with pleasure the one inspiring teacher or the one helpful critic whose influence was vital in our making, whose inspiration stands out clearly as a landmark on our journey onward and upward. It is my firm conviction that the torch of knowledge, of culture, of inspiration, is passed on from hand to hand, from individual soul to individual soul, *not* from the individual to a mob or even to a committee. You may recall the advice which Oliver Wendell Holmes gave to his son when he entered Harvard—the same son who is now associate justice of the United States Supreme Court. "My son," he said, "I would advise you not to choose courses; choose *men.*" And one of the professors he was urged to choose was Henry Wadsworth Longfellow.

In the personal conference with the instructor all the faults of the individual student turn up—mental obliquities, faulty preparation, lack of logic, deficiencies in language. The first great virtue to be impressed upon the student is the absolute need of intellectual integrity. It is *the* fundamental virtue. Without it there can be no progress in science nor any upward trend in social evolution. A candidate who discloses a laxness or an obliquity in this one ethic should be discouraged or prevented from taking a Ph.D. degree. The poorest use any university can make of its funds is to train cheats and thieves.

The faults in preparation are legion. It seems that few candidates, in the scientific departments at least, are adequately prepared in English. It is claimed, and I think truly, that few scientific men in America can either write or speak effectively. Certain it is that in our department by far the most of our time in coaching candidates for higher degrees is spent, first in the application of logic in the analysis of the problem and the organization of material for presentation; and, second, in the presentation of their findings in acceptable English. The latter, as a rule, is the harder problem.

What do the schools do with their time? The majority of students are inadequately prepared in English when they enter college. And the majority of them are still weak sisters in English when they come into graduate work.

In our particular longitude we are still handicapped with the poverty of our pioneer fathers. With the best of intentions and ideals it has not been possible to provide all comers with adequate consecutive schooling. We have endless wealth, but it is not well distributed. The most of the students in advanced work even at the present time are sorely handicapped by the need of earning their daily bread and of laying by a fund to pay for an education. This makes it impossible for the student to get consecutive training. It burdens him with work and responsibility, which are alien to scholarly growth. It brings him often to his advanced work rusty and weary, and without the fire and elasticity of youth.

These handicaps are tragically hard, and they are the lot of most of the candidates for Ph.D. degrees with whom *we* have to deal. Yet as handicaps they do not compare with *easy money,* with *wealth assured.* Studies have been made which show that up to the present time the men and women in this country who have made the bulk of worthy contributions in productive scholarship, in science, art, literature have come from the farms and villages, and from homes of moderate wealth or no wealth. So far as my observation goes, easy money in the hands of the student, with its evil concomitants of idleness, dissipation and impatience, goes farther to prevent achievement in scholarship than all the poverty of pioneer conditions.

This does not augur well for the future of productive scholarship in America. For we are immensely rich, and growing rapidly richer. And there seems to be a disposition on the part of the college administrations hither and yon to put up the financial bars higher and yet higher. At every boost of the tuition rate some discouraged young men and women have to drop out. They can not make the two ends meet. Of course there are plenty of applicants ready who are not embarrassed by high tuition rates. The number of students who *come* to college grows less, and the proportion of students who are *sent* to college increases. In an institution of restricted enrolment, like our own, it will not be long before it has become a rich man's college. But that, for obvious reasons, will be an evil day for the future of productive scholarship. Out of such a college candidates for worthy rank in higher education fail in large measure to materialize.

It is doubtless idle to complain about this condition. But some one with vision ought to face it without delay. And generous people *have* thought of it, and have endowed scholarships and fellowships. But that is not an unmixed blessing. A fellowship which furnishes tuition, and a financial margin over, which the candidate can count on to help defray his living expenses, may provide just the condition which will make it possible for a worthy candidate to carry on, in his graduate work. So universities have vied with each other. The better-endowed institutions offer more fellowships, and financially more attractive ones, and the search for a fellowship may become a game. The candidate may shop around, in his choice of an alma mater. If so he no longer chooses courses, or even *men*, he chooses bargains.

Giving money outright is an exceedingly hazardous venture. The hardest thing a man of wealth has to do is to give without pauperizing the recipient. Why not tackle this situation seriously, and try to improve it? Wouldn't it be vastly better for us to give one third, say, of all the students admitted to our graduate work free tuition, on the basis of distinction in scholarship and fine promise of accomplishment. And as an incentive in graduate work, in aid of those financially handicapped, offer as large as possible a number of fellowships which carry free tuition, and the privilege of borrowing from a loan fund at no interest during the period of residence and at a low rate of interest thereafter; but the loan to be paid back as fast as the candidate is able to pay, when he resumes his regular work. The idea is not a new one. Such funds are in successful use in our own university, but they should be greatly amplified.

Such fellowships should be given only to candidates of exceptional merit and proved ability. The granting of such fellowships does not tend to pauperize the recipient, and the award repaid, becomes a perpetual fund, in aid of worthy students forever.

II

Let us now consider the doctor's business after he is *made*. That, after all, is the reason there are universities. Think of the rate at which doctors are being turned out! What becomes of them all? The original doctors were trained avowedly as teachers. But a wonderful change has come over our education in the last two generations. Science in its many aspects has led all departments in the number of degrees granted. Chemistry, physics, geology, engineering and biology, including bacteriology, are furnishing the expert investigators who are building the scientific foundations in industry, commerce, sanitation and preventive medicine. But in spite of that the most of the doctors are still in the teaching profession. Of the 1,374 Ph.D. degrees granted at Yale, 712—over half of all of them—are in college teaching or administrative positions, and I have no doubt that much the same story will be told by other universities when the facts are assembled.

Some alarm was expressed in Germany not long ago, that there were too many doctors being produced. But it depends upon what field the doctorate is in. There are not many positions open for doctors in Latin, Greek, Sanskrit and Egyptian. The market can be easily overstocked. In the first year of the great war a German doctor in geography came into my horizon, wanting a place to earn a living. His specialty was in ancient maps. I asked him about a map issued about 1790, but he quickly assured me that he didn't pretend to know anything about maps later than 1760!

But think of the opportunity for service in preventive medicine, whether the special study be in bacteriology or in chemistry! Think of the revolution already wrought by chemistry in synthetic dyes and resins and fuels and drugs! Think of the marvelous developments in physics, especially in electricity, in motors, in lighting, in the telegraph, telephone, radio! One manufacturing company alone, the Du Pont company, has over 300 Ph.D.'s in constant service and is taking on more all the time, and many other industries are falling into line.

The researchers in these various sciences have provided for more progress in the world in the last two generations than was won by all the brains and brawn of the men of the preceding 200 centuries. And we are just beginning our great march of scientific conquest.

But at the present moment, more than half of our doctors must look for teaching positions. Here again there is room for criticism and need for improvement. Most of these potential teachers have spent most of their time in compassing the subject-matter of their field, seemingly unaware that teaching is an art, and that, like any other art, excellence in it is arrived at through careful training, almost, as our fathers would say, by fasting and prayer. And while for positions in high schools, as principals and superintendents, special training in pedagogy is expected or required, it is not so for teaching positions in colleges and universities. Young doctors are plucked raw from the convocation and plumped into responsible teaching positions, often with evil consequences. I have been told by reliable observers that they have seen worse, half-baked performances called teaching in classrooms of our university than one might ever expect to find in high schools. We do not need to suppose for a moment that our university is exceptional in that regard.

I am told that at least one leading university in Canada has for some years required of Ph.D. candidates some serious preparation in the art of teaching on the part of those planning to accept teaching positions. It is high time that our colleges and universities took similar action.

Until such action is taken, we should help our young doctors to think gravely and seriously of the responsibilities and opportunities of the teaching profession. The first position is not likely to carry a generous salary. But let's not be so naïve as to seem to excuse our sloppy teaching on that score. I remember an honest Minnesota girl who had a school, and not much education or skill to go with it. When some one called attention to her poor work, she excused herself by saying, "Ah, it's little they pays me an' it's little I taches thim."

Research is good, and the extension of the horizon of human knowledge is good. But it may be good for nothing, if it can not be translated into the lives and accomplishments of mankind. Many a researcher's efforts have been lost because human society was not ready to make use of the new knowledge. Let us never forget Thomas Huxley and his teaching—a great scientist adding great contributions to the sum of human knowledge, but a great teacher as well, and never satisfied until his science could be "vulgarized," as the French express it, that is, until his science could be presented clearly to intelligent people not specialists in science. *That* is the teacher's mission, his opportunity for human service. And I wish that each one of the army of new doctors who goes out to his chosen work each year, whether in teaching or in research, might take with him the spirit of Huxley, as a real religion in his daily work. I can not wish for him greater happiness.

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SCIENTIFIC EVENTS

THE IMPERIAL CHEMICAL HOUSE IN LONDON[1]

NOT content with its achievement in erecting a landmark in the history of chemical industry, Imperial Chemical Industries, Ltd., has provided the Imperial metropolis with an outward and visible expression both of its work and of the status which that work has won for the company. Down by the River Thames, close to the Houses of Parliament (the division bell of which rings on the directors' floor) there has arisen in a surprisingly short time a noble building designed by Sir Frank Baines to combine beauty of form with commercial efficiency of a high order, and that degree of comfort which ministers to both; many will like to regard it as a new monument dedicated to chemists, physicists, engineers and chemical engineers of the past, the present and the future—a whim which will seem not altogether to lack reality when the carved portraits of Liebig, Priestley, Ludwig Mond, Alfred Mond, Harry McGowan, Lavoisier, Mendeléef, Cavendish, Dalton and Berthelot are seen surmounting the arches of the main façades. Faraday is selected for special honor, for one of the panels on the massive main door—that intended to represent the achievements of modern science—will portray a lecture by Faraday at the Royal Institution.

Imperial Chemical House, which had to be designed while the construction progressed, contains 700 rooms, with a total floor area of 370,000 square feet, and its successful completion in less than one third of the time which would normally have been required is no empty tribute to the efficiency of the scientific coordination and control which has been applied to the task. Modern methods have been freely brought into service; ultra-violet rays will penetrate into the rooms; rubber flooring will contribute its special advantages; the artificial lighting will be exclusively of daylight quality. The requirements of a large staff have been amply and sympathetically considered; there is carving in the spirit of Grinling Gibbons and in the technique of the Wren period; the globe desk-lights bear a map of the world. These three representative facts in juxtaposition surely indicate that the company intends to advance beneath a banner inscribed "What is worth doing is worth doing well."

[1] From *Nature*.

THE NEUROLOGICAL INSTITUTE OF NEW YORK

OF the $2,000,000 required to erect and equip the new building of the Neurological Institute at the Medical Center, $1,800,000 has been raised, and the trustees of the institute now seek $2,000,000 additional for research.

The building, at Haven Avenue, 168th Street, west of Broadway, was dedicated on March 15 in the presence of distinguished neurologists from New York and other cities, officers of the institute and of Columbia University, officials of city and state, leaders in philanthropy and representatives of medicine and allied sciences.

The speakers included Robert Thorne, president of the institute; General William Barclay Parsons, chairman of the trustees of Columbia University; Commissioner Frederick W. Parsons, of the Department of Mental Hygiene of the State of New York, and Dr. Frederick Tilney, professor of neurology and neuro-anatomy in the Columbia Medical School.

The institute began to operate actively on March 18, vacating the building on East 67th Street, which it had occupied since it opened its doors for the reception of patients on October 1, 1909, and which was originally built for a Nurses' Home for Mount Sinai Hospital.

While it is an independent corporate entity under its own board of trustees, the institute will function as a teaching unit of Columbia University. Most of the members of its medical board are drawn from the Columbia medical faculty, and all clinical teaching at Columbia in the field of neurology will hereafter be carried on there.

An analysis of medical data shows that one out of every twenty-five persons in the United States will spend some part of his life in a hospital, receiving treatment for nervous or mental disease. The Neurological Institute is said to stand alone not only in New York but in the United States as an institution devoted exclusively to prevention, cure and research in this sphere.

The largest contributors to the institute were J. P. Morgan and William Bingham, 2nd, each of whom gave $200,000. Mr. Morgan's gift provides for the establishment of wards for the study of sleeping sickness, of which his wife died. Mr. Bingham's contribution was made in honor of Dr. John George Gehring, a neurologist of Bethel, Maine, to whom a fully equipped floor of four wards will be dedicated. The donor is a former patient of Dr. Gehring.

Edward S. Harkness, Jr., gave $150,000; Miss Ruth V. Twombley, $110,000; Harrison Williams and Clarence Dillon each $100,000; Felix M. Warburg, Mrs. Felix M. Warburg, Mrs. William A. M. Burden, Mrs. Henry P. Davison and Alfred M. Heinsheimer made gifts of $50,000 each, and smaller sums were received from a large number of contributors.

THE COLUMBUS MEETING OF THE AMERICAN CHEMICAL SOCIETY

THE seventy-seventh meeting of the American Chemical Society will be held in Columbus, Ohio, from April 29 to May 3, under the presidency of Dr. Irving Langmuir, of the General Electric Company. Before sixteen divisions of the meeting hundreds of papers will be read by leaders in their respective fields.

On May 1, Dr. C. E. Kenneth Mees, research and development director of the Eastman Kodak Company of Rochester, N. Y., will discuss "The Formation of the Photographic Image" and present a film showing the rotation of Jupiter. On April 30, at a symposium on "Economic Relations between Chemistry and Agriculture," the speakers will include H. W. Jeffers, of the Walker-Gordon Dairying Company of New York; C. H. MacDowell, of the Armour Fertilizer Works of Chicago; Major T. P. Walker, of the Commercial Solvents Company of Terre Haute, Ind.; William Haynes, of New York, who will preside, and R. J. Mackay, who is chairman of the Division of Industrial and Engineering Chemistry, which has arranged the discussion with a view to showing how much relief the farmer may expect from chemistry.

All divisions will meet with the exception of the divisions of Dye Chemistry, Fertilizer Chemistry and Leather and Gelatin Chemistry.

The Division of Biological Chemistry will hold three sessions, one jointly with the Division of Medicinal Chemistry. Papers are desired bearing on any phase of the chemistry of the constituents of living matter and their relation to vital processes in health and disease, including nutrition, vitamins, irradiation, endocrinology, etc.

The Division of Chemical Education is planning to devote two half-days to miscellaneous papers and two to a symposium on "Lecture Experimentation." There will be a breakfast meeting of the executive committee at 8 A. M., Monday, April 29; a breakfast meeting of the senate at 8 A. M., Wednesday, May 1, and at noon on May 1, a luncheon, to which all high-school teachers in the area will be invited. The division has been invited to visit the Ohio Wesleyan campus. The editors and contributing editors of the *Journal of Chemical Education* will meet at 5 P. M. on Wednesday, May 1.

The symposium on "Lecture Experimentation" of the Division of Chemical Education will afford an excellent opportunity for the following types of displays: (*a*) exhibits by manufacturers of chemical apparatus; (*b*) exhibits of high-school and college student laboratory projects (or photographs of same), including graphs and charts, and (*c*) exhibits of new or unusual charts and apparatus set-ups used in the teaching of chemistry. Free space in the chemistry building of the Ohio State University will be reserved on request, provided wall or table space is specified. The local committee will receive and put on display all exhibits unless instructed to the contrary and will do its best to protect them, but can not assume any responsibility for breakage or loss.

The Division of Physical and Inorganic Chemistry, in addition to the general program on Tuesday morning, will hold a general symposium on "Molecular Structure" and sessions for miscellaneous papers. The Division of History of Chemistry will hold one half-day session. It is planning, as usual, an exhibition of historical material. The Division of Sugar Chemistry is arranging a symposium on "Molasses." This, together with miscellaneous papers, will take up two half-day sessions. The Division of Industrial and

Engineering Chemistry, in addition to the general meeting on Tuesday morning and its joint session on Wednesday with the Division of Water, Sewage and Sanitation Chemistry and the Division of Gas and Fuel Chemistry, will have a half-day session given over to miscellaneous papers. The Division of Water, Sewage and Sanitation Chemistry will hold a symposium on "Boiler-Room Chemistry," with W. D. Collins as chairman, jointly with the Division of Gas and Fuel Chemistry and the Division of Industrial and Engineering Chemistry.

THE HAYDEN MEMORIAL GEOLOGICAL AWARD

THE committee of the Academy of Natural Sciences of Philadelphia, which was appointed to select a recipient for the Hayden Memorial Geological Award for 1929, has unanimously nominated Dr. Charles Schuchert, professor emeritus of paleontology in Yale University, and the council of the academy has approved this award. The committee consists of: Dr. Henry F. Osborn, Dr. Henry A. Pilsbry, Dr. William B. Scott, Dr. Edgar T. Wherry and Dr. R. A. F. Penrose, Jr., *chairman*. The award was given in recognition of the distinguished work of Dr. Schuchert in invertebrate paleontology, paleogeography, historical geology and the migration of faunas.

The Hayden Award was founded in 1888 by Mrs. Emma W. Hayden as a memorial to her husband, Dr. Ferdinand V. Hayden, director of the U. S. Geological and Geographical Survey in the early days of that organization. The award at first consisted of a bronze medal with an honorarium in cash, but it now consists simply of a gold medal, and is given for preeminent research in geology, paleontology or in related sciences. This award has been presented at different times to many of the most noted geologists, paleontologists and mineralogists in America and Europe.

FAREWELL DINNER FOR SECRETARY JARDINE

SECRETARY JARDINE, who retired from the cabinet on March 4, was the guest of honor at a Department of Agriculture dinner given by the directors, bureau chiefs, former bureau chiefs, and assistants to the secretary at the Cosmos Club, Washington, D. C., on February 23. Miniature portraits of the secretary on hand-lettered cards served as place cards for the guests and as mementoes of the farewell gathering. Dr. A. F. Woods, director of scientific work, presided, and brief talks were made by Secretary Jardine; T. H. MacDonald, chief of the Bureau of Public Roads; Dr. Louise Stanley, chief of the Bureau of Home Economics; Dr. C. C. Clark, assistant chief of the Weather Bureau, and M. S. Eisenhower, director of the Office of Information. Secretary Jardine said that the last four years had been the happiest of his career. He paid high tribute to the character, intelligence and industry of the men and women who make up the Department of Agriculture. The fact that many pieces of constructive legislation for agriculture have been adopted, that research funds have been greatly increased, and that the employees generally feel that much progress has been made, gave him cause for deep gratification. He spoke especially of the spirit of cooperation which he said prevailed in the department, and said the path of any Secretary of Agriculture is made easier by such a spirit. He concluded by saying that he would rather have represented the farmers of America in the cabinet than to have held any other office within the gift of the American people. The secretary was presented with a volume of autographed portraits of those who have worked with him in the last four years, and in presenting it Mr. Eisenhower said it carried the admiration, respect and devotion which all the employees had for him deep in their hearts.

THE RETIREMENT OF MR. FRANK LEVERETT

DR. GEORGE OTIS SMITH, director of the U. S. Geological Survey, has addressed under date of March 6, 1929, a letter to Mr. Frank Leverett, at Tucson, Arizona, in which he writes:

I wish to extend to you my hearty congratulations on the nearly forty-three years of active service in the U. S. Geological Survey's Section of Glacial Geology, which you will have completed by the date of your retirement, March 9, 1929.

Your record shows large productivity in the form of published official reports and other contributions to the records of glacial geology of the North American continent as the result of your energetic, painstaking and long-continued investigations, in field mapping and office study.

. . . . . .

The total of results of your work thus far, as represented by these numerous reports and other papers and by other unpublished material, is highly commendable and I congratulate you upon it. The high quality as well as the great quantity of your work, your long experience effectively utilized and the original contributions that you have made in advancing the science of glaciology to its present position have led to your recognition by geologists the world over as one of the leaders in your field. It is my hope that good health may be vouchsafed to you for many years to come, and that the science of geology may be still further enriched by the results of your future investigations.

SCIENTIFIC NOTES AND NEWS

THE council of the British Association will nominate Dr. F. O. Bower, F.R.S., lately regius professor of botany in the University of Glasgow, as president of the association for the year 1930, when the meeting will be held in Bristol. The association has received from the Court of Common Council the expression of a hope that London will be selected as the place of meeting in the centenary year, 1931, and offering entertainment to the association in that event. This invitation has been accepted, and the centenary meeting will therefore be the first ever held in London.

THE council of the Royal Society, at its meeting on February 21, recommended for election into the society the following fifteen candidates: Arthur John Allmand, professor of physical and inorganic chemistry, King's College, London; Arthur Henry Reginald Buller, professor of botany, University of Manitoba, Canada; Charles Drummond Ellis, university lecturer in physics, University of Cambridge; Ronald Aylmer Fisher, head of the statistical department, Rothamsted Experimental Station, Harpenden; George Ridsdale Goldsbrough, professor of mathematics, Armstrong College, Newcastle-on-Tyne; James Gray (Cambridge), fellow of King's College and lecturer in experimental zoology, University of Cambridge; Cyril Norman Hinshelwood, fellow and tutor of Trinity College, Oxford; Augustus Daniel Imms, head of the entomology department, Rothamsted Experimental Station, Harpenden; Peter Kapitza, assistant director of magnetic research, Cavendish Laboratory, Cambridge; William Dickson Lang, keeper of the department of geology, British Museum; John Mellanby, professor of physiology, University of London; Henry Stanley Raper, professor of physiology, University of Manchester; Harry Ralph Ricardo, consulting engineer; Harold Roper Robinson, professor of physics, University of South Wales, Cardiff, and Frederick William Twort, professor superintendent of the Brown Animal Institution, London.

THE council of the Royal Society of Edinburgh has awarded the Gunning Victoria jubilee prize for 1924 to 1928 to Professor E. T. Whittaker, F.R.S., in recognition of his distinguished contributions to mathematical science and of his promotion of mathematical research in Scotland. The Makdougall-Brisbane prize for 1924 to 1928 has been awarded to Dr. William Ogilvy Kermack, for his contributions to chemistry, published in the society's *Proceedings* and elsewhere.

DR. WILLIAM SYDNEY THAYER, emeritus professor of medicine of the Johns Hopkins Medical School, has been appointed Gibson lecturer of the Royal College of Physicians of Edinburgh for the triennial period 1929–31.

IN recognition of the research work being done in the department of biochemistry of the University of California, the Chemical Foundation has granted to Dr. C. L. A. Schmidt, chairman of the department, a fund of $2,500 a year for the next five years to support his studies of proteins and amino acids. In addition, the Board of National Research Fellowships in the Biological Sciences has awarded two of the three fellowships allotted to biochemists to members of the staff of the university department of biochemistry, Dr. D. M. Greenberg and Norval Burk.

THE University of Pennsylvania conferred the honorary degree of doctor of science on Dr. Herbert E. Ives, of the Bell Telephone Laboratories, at the University Day exercises on February 22.

DR. J. C. TH. UPHOF, professor of botany at Rollins College, has been elected corresponding member of the Netherlands Geographic Society at The Hague.

DR. ANTONIO LAGORIO, director of the Chicago Pasteur Institute, completed his fiftieth year in practice on February 25, having graduated from Rush Medical College in 1879.

H. HOBART PORTER, engineer and industrialist of New York City, has been elected chairman of the Engineering Foundation. He succeeds Lewis B. Stillwell, who has served since 1925. Officers reelected by the foundation include: George A. Orrok, New York, and Dr. Arthur D. Little, Cambridge, *vice-chairmen*, and Dr. Alfred D. Flinn, New York, *director*.

DR. ARTHUR BEVAN, assistant professor of geology at the University of Illinois, has been appointed state geologist of Virginia. He will continue at the university until the end of this semester. The headquarters of the Virginia Geological Survey are at the University of Virginia at Charlottesville.

CHARLES H. BURKE, commissioner of the Bureau of Indian Affairs, has tendered his resignation.

PROFESSOR GUISEPPI CARONIA, head of the Institute of Epidemiology at Naples, has joined the staff of the Hooper Foundation for Medical Research of the University of California.

AN exchange of professors in the field of forest utilization has been approved by the University of California and by Cornell University. Professor Emanuel Fritz, of the University of California, will teach at Cornell University, and Professor A. B. Recknagel, of Cornell University, will go to the Uni-

versity of California. The former has been at the University of California since 1919, teaching wood technology and lumbering. Professor Recknagel has been at Cornell University since 1913 and is now teaching wood technology, forest utilization and forest management.

GEORGE A. PERLEY has resigned as associate professor of chemistry at the University of New Hampshire and will become associated with the Leeds and Northrup Company, of Philadelphia, where he will have charge of the electrochemical and physical-chemical research and development.

DR. E. M. HARVEY, professor of horticultural research at Oregon State College, Corvallis, leaves from San Francisco on March 27 to attend the fourth Pacific Science Congress, to be held at Batavia and Bandoeng, Java, from May 16 to 27. He will also visit agricultural experiment stations in Japan and England.

DR. WILLIAM BEEBE and his party landed on March 15 at St. Georges, Bermuda, and went at once to Nonesuch Island, which had been placed at his disposal by the colony. As has already been reported in SCIENCE, Dr. Beebe plans to spent six or eight months in scientific work for the Bermuda Oceanographic Expedition under the auspices of the New York Geological Society.

THE second course of the William Sydney Thayer and Susan Read Thayer lectureship in clinical medicine was given at Johns Hopkins University School of Medicine, Baltimore, on March 7 and 8, by Dr. George R. Minot, professor of medicine, Harvard University Medical School, and director of the Thorndike Memorial Laboratory, on "Treatment of Pernicious Anemia" and "Treatment of Anemia other than Pernicious Anemia, particularly with Diet and Iron." The 1928 lecturer on this foundation was Sir Humphry Rolleston. A group of friends of Dr. Thayer's donated a fund to the university in 1927 to endow the lectureship.

DR. CHARLES J. CHAMBERLAIN, professor of morphology and cytology in the University of Chicago, on February 26 and 27 gave three addresses at Miami University under the auspices of the department of botany. Two of these lectures, one on "The Living Cycads" and the second, "Botanizing in New Zealand," were illustrated.

DR. MAXIMILIAN TOCH delivered a public lecture on March 15 in the Carnegie Lecture Hall in the University of Pittsburgh, on "Paints, Paintings and their Restoration," with special reference to the scientific determination of the genuineness or forgery of paintings.

DR. J. J. SEDERHOLM, director of the Geological Survey of Finland, who was recently awarded the Penrose medal by the Geological Society of America, is visiting the University of California this month, giving a series of twelve public lectures on the "Pre-Cambrian Problems in Fenno-Scandia."

DR. LEWIS BRINTON, known for his investigations of diseases of the gastro-intestinal tract, died in Philadelphia on March 13 at the age of sixty-four years.

THE fifth National Shade Tree Conference was held at the Brooklyn Botanic Garden on February 7 and 8, not at New Haven as reported in SCIENCE.

AT the suggestion of the Faraday Society, arrangements are now being made for the interchange of membership privileges between the Faraday Society and the American Electrochemical Society. Heretofore members have merely had the privilege of subscribing to the *Transactions* of the Faraday Society at a reduced rate. It is now contemplated to give the members of the American Electrochemical Society full membership in the Faraday Society at a reduced rate, and *vice versa*.

THE Italian Association for the Advancement of Science recently held its seventieth session in Turin, under the chairmanship of Professor Filippo Bottazzi, physiologist of the University of Naples. There were section meetings and general sessions. In his opening address, according to a report in the *Journal* of the American Medical Association, Professor Bottazzi gave a brief account of the history of the society, which began its annual meetings in 1839 and has continued them up to the present, with the exception of twenty years from 1842 to 1862, the period of the wars for Italian independence. However, the society has lacked the necessary means to perform its two fundamental tasks: the advancement of science and the spread of scientific culture throughout the country. Furthermore, in the little that has been done some errors have crept in, among which may be mentioned that of having held that there are two distinct forms of science, which exist independently of each other, a pure science and a practical science, and that of having preferred the so-called practical science. In the few gifts that have been made, preference has been given to physics and chemistry, to the neglect of biology. The speaker requested of the minister of public instruction the creation of a biologic laboratory of research on aeronautics, asphyxiating gases and alimentation.

THE expedition under the auspices of the Naval Observatory, Washington, D. C., which sailed on January 28 for the Philippines to observe the solar eclipse on May 9, left Manila on March 5 for Iloilo, P. I.,

where a base will be established. The minesweeper, U. S. S. *Penguin*, which is carrying the party to Iloilo, has been assigned as station ship for the expedition, which is headed by Commander C. H. J. Keppler, U. S. N. The party includes Paul Sollengerger, from the Naval Observatory; Lieutenant H. C. Kellers, medical corps, U. S. N., and Professor and Mrs. William A. Cogshall, of the University of Indiana. The base will probably be established on the grounds of the Philippines Railway Company, Iloilo, which has offered every assistance.

A PARTY of geologists and advanced students, under the leadership of Professor R. M. Field, of Princeton University, will make a six weeks' trip to the British Isles beginning July 14. The annual American train-tour of the Princeton summer school of geology and natural resources will begin June 27 and traverse Canada. A special Pullman car fitted for lectures, dining and sleeping will accommodate 23 students.

IT is reported in the London *Times* that the preliminary arrangements in connection with the new expedition to the Antarctic, which will be under the leadership of Sir Douglas Mawson, are well advanced, and it is expected that the *Discovery* will sail in June. Captain J. K. Davis, director of investigation, Marine Department, Commonwealth Government, who will act as second-in-command of the expedition, will arrive in London at an early date, and will navigate the *Discovery* to Australia. Sir Douglas Mawson does not propose to sail in the vessel from London, but will join her in the Antipodes. It is probable that the expedition will set out from Hobart, Tasmania, towards the end of the year. Sir Douglas Mawson is reported to have stated that he was completing certain arrangements here and the remainder would be dealt with in Australia. There will be a scientific staff of ten, and the *Discovery*'s crew will number twenty-six. He hoped to carry out oceanographical investigations, and a coast-line survey would be an important feature of the work.

THE New York Hospital and Lying-In Hospital have agreed to merge, the union to be effected in the near future. The merged hospitals, according to the announcement, will become an integral part of the project for the care of the sick, for teaching and research in the New York Hospital-Cornell Medical College Association. By agreement with the Lying-In Hospital, about $8,000,000 in resources is made available for the association. This money will be used for the building and the work of a maternity hospital between Sixty-eighth Street and Seventieth Street, overlooking the East River. This will constitute an institute devoted to the care of women and infants, teaching and research. Mr. J. P. Morgan and the Laura Spelman Rockefeller Memorial, through Mr. John D. Rockefeller, Jr., the society announced, have given $2,000,000 each toward the new maternity hospital. George F. Baker and George F. Baker, Jr., gave $1,000,000 each. The remaining $2,000,000 available under the agreement will come from the present assets of Lying-In Hospital.

AT a dinner of the board of trustees of the Research Fund of the American Otological Society, Inc., at the Academy of Medicine on March 12 plans were considered for raising $2,500,000 for the study of deafness. Dr. Arthur B. Duel, who is chairman of the board of trustees of the Research Fund, stated that Edward S. Harkness has already pledged a gift of $100,000 on condition that $400,000 more be raised by July 1. Starling W. Childs has also pledged $25,000 with the same provision.

THE bill making appropriations for the Department of Agriculture for the fiscal year 1930, which begins July 1 next, was approved by President Coolidge. Funds carried in this act, together with certain special appropriations which become available automatically at the beginning of each year, will make a total of $156,995,030 available for 1930. Of this amount $82,000,000 is for road building. Increases in the bill for the work of the department and for payments to states for other than road purposes total approximately $4,700,000. Decreases carried in the bill, many of which are due to the omission of non-recurring items, amount to approximately $1,000,000, making a net increase of about $3,700,000.

A COOPERATIVE arrangement with the American Petroleum Institute and the Special Libraries Association has been made by the Department of Commerce, whereby the organizations named will assist the Bureau of Mines in the preparation of the monthly bibliography covering current articles, books and reports dealing with petroleum and allied substances. This monthly bibliography is distributed by the San Francisco field office of the Bureau of Mines to approximately 500 oil companies and others interested. Under this cooperative agreement trade journals will be abstracted by the various members of the Special Libraries Association and the material sent to the Bureau of Mines' bibliographer at the San Francisco petroleum field office for compiling and inclusion in the monthly bibliography.

UNIVERSITY AND EDUCATIONAL NOTES

IT is announced that the University of Texas, under a compromise agreement in the district court, will re-

ceive approximately $1,000,000 and the heirs of W. J. McDonald, Texas banker, the remainder of an estate valued at about $1,350,000.

THE dean of the medical school of the University of Oregon, Dr. Richard B. Dillehunt, announces that the Rockefeller Foundation has given $400,000 to the medical school, $300,000 of which will be used to construct a new clinic building on Marquam Hill, Portland, and the remainder for equipment.

AT Harvard University one or more scholarships in mining geology will be made possible by the gift of $10,000 made in memory of Carlton Thayer Brodrick, '08, by his father and mother, Mr. and Mrs. Alfred H. Brodrick, of Newton Highlands.

FOR the promotion of scientific research by graduates three fourths of the freshman class at Lehigh University have relinquished chemical laboratory refunds in favor of the student chemical foundation. These refunds consist of balances remaining at the end of the year from deposits made at the beginning of each semester to cover the cost of material used in the laboratory. The total amount to be turned over, it is estimated, will be $5,000 this year. Of this sum, $1,500 will be used for two graduates in chemical engineering to carry on research next year and the balance will be used to build up a permanent fund of $50,000.

DR. SAMUEL T. ARNOLD, associate professor of chemistry at Brown University, has been appointed acting dean during the absence of Dean Otis E. Randall, who has leave of absence.

PROFESSOR E. A. MILNE, of the University of Oxford, will give a course of lectures on "The Physics of the Stars" during the summer session of the University of Michigan.

PROFESSOR A. H. COMPTON, of the University of Chicago, has been appointed a member of the 1929 summer session staff in physics at Cornell University. He will give courses dealing with "X-Rays and Electrons."

DR. THEOPHILUS S. PAINTER, of the University of Texas, has been appointed professor of biology for the summer session of 1929 at Western Reserve University. Dr. Painter will give two series of lectures on different aspects of cytology.

ACCORDING to *Popular Astronomy*, Dr. Knut Emil Lundmark, of the Observatory of Upsala, has been appointed professor of astronomy in the university and director of the observatory at Lund as the successor to Professor C. V. L. Charlier, who recently retired. Professor H. Vogt, of the Königstuhl Observatory, Heidelberg, has been called as director of the observatory and as professor of astronomy at the University of Jena.

DISCUSSION

WHAT IS THE TYPE OF A GENUS?

THE necessity for a concrete type specimen, which fixes the identity of a species with objective definiteness and can be referred to as absolutely authoritative in spite of eventual errors in description, is now almost universally recognized. The usefulness of the type specimen has become so clear that we may expect presently to regard it as indispensable, and provide accepted substitutes in cases where there were no original types or where these have been lost.

The need for the same objective typification in the case of genera is equally manifest, but the codification of rules is more needed in this case, and the best method of satisfying the need of types is not clear. I have been trying for a long time to locate objective types of the acceptable genera of *Polypodiaceae,* and have encountered difficulties in principle as well as in detail. What is agreed upon is that a genus must have a type species. In the easy, simple instances, this is sufficient; the genus has a type specimen in that of its type species. This is true even without any agreement that a genus needs a type specimen.

But a couple of examples will show the need of rules or laws, and of a court to interpret and apply them. Take the genus *Ptilopteris,* of Hance.[1] It was duly defined and explained in Hance's elegant Latin, concluding: "Duae tantum hucusque mihi certe innotuerunt species: has inquam:

1. Pt. Hancockii, sp. nov. [which is then diagnosed, and]
2. Pt. Maximowiczii (=Polypodium Baker!)."

The second of these represents a genus, not previously recognized, so distinct that its affinity is not yet agreed upon, and in complete agreement with Hance's generic diagnosis. The first is a *Polystichum,* absolutely at home in that genus, and not even in full conformity with Hance's diagnosis of *Ptilopteris.* The rule that the type species of the genus shall be the first species listed under it (in the absence of another specified type), would reduce *Ptilopteris* to synonymy with *Polystichum* and leave *Pt. Maximowiczii* without a tenable generic name. The Kew suggestion, that "standard species" be adopted, will meet the difficulty in this case. *Pt. Maximowiczii* can be the standard species and its type specimen *may* be that of the genus. It is clear, from the fact that it agrees with his diagnosis while his first species does not, that this fern was the real subject of his generic diagnosis. But then, is the type specimen of *Ptilopteris* the one Hance used as the basis of his generic

[1] *Journal of Botany,* 22: 188, 1884.

description, or is it, as just suggested, the type specimen of the species *Polypodium Maximowiczii* Baker? The question itself shows the need of generic type specimens. My judgment is that in this case it should be Hance's specimen. He described a recognizable and distinct genus, and it would serve no purpose to render this genus nameless by showing that he was in error in the identification of the plant he based it on. He seems to have been correct; but there are very many known instances in which men have been wrong in such cases. The difficulty in the way of a rule sanctioning the recognition of Hance's specimen as the generic type is that such a rule would leave it impossible to locate any type for a great many genera.

Campium, Presl, Tentamen Pteridographiae (1836) 238, is a similar but more complicated case. The first species listed is "Campium punctulatum (Acrostichum punctulatum Presl nec Lin.)." I have reason to believe that this does not belong in the genus Presl described (it was based on a sterile specimen), and that *C. preslianum* (Fée), which Presl later accepted as a substitute name, is a different fern. Here, again, a standard species will standardize the genus. It will be *C. costatum* (Wallich) Presl, the second of the species listed and the only other one discussed or figured. In this instance the type almost must be Presl's specimen, in spite of his citation of Wallich, because the names in Wallich's List are now regarded as *nomina nuda.* There are still other possibilities: Christensen's view is that *Campium costatum* was left a *nomen nudum* by Presl.

One more example: *Hemigramma.*[2] This genus was published as comprising a single species, *Hemionitis Zollingeri* Kurz. By general present consent, this is a synonym of *Gymnopteris latifolia,* named by Meyen and described by Goldman, the proper name being *Hemigramma latifolia.* If the generic type is fixed by Christ's citation, the type of the genus is not the type of any valid species. If the generic type is that of the species Christ really founded his genus on, *H. latifolia,* it is a specimen Christ not only never saw, but which he explicitly regarded as a different fern. The actual, material foundation of Christ's diagnosis was a collection of specimens of which the first cited was *Borden no. 2124.* Taking this case by itself, the most reasonable view would be that the type specimen of the genus is Christ's specimen of Borden's collection. The objection to a rule to this effect has already been indicated.

I am very sure that we must come to the recognition of type specimens of genera. The question of what these types shall be, or at least the general principles underlying their fixing, will have to be decided by a congress, and the subject is brought up now to stimulate discussion, so that action by a congress may not be ill considered. What is the type of *Hemigramma?*

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[2] Christ, *Phil. Journ. Sci.,* 2c: 170, 1907.

BIOLOGICAL CONTROL OF THE PRICKLY PEAR

THE brief account of the prickly pear work in Australia, given in SCIENCE of January 18, suggests the desirability of some additional comments. Last year I had the pleasure of visiting the experiment station at Sherwood, near Brisbane, and was able to see what was going on and have it all explained to me by Mr. Alan P. Dodd. I was especially struck by the thoroughness of the work, the careful survey of the enemies of *Opuntia* in various countries, and the extreme care taken to avoid introducing undesirable insects. Some insects which might be serviceable against prickly pear will occasionally attack other plants, and if experiments show that any such danger exists, they are not used. On the other hand, the safe and valuable species are pushed with vigor. The moth *Cactoblastis cactorum* has been known since 1885, when Berg described it from Argentina as *Zophodia cactorum.* The French entomologist Ragonot, in the Romanoff Memoires, 1901, established for it the genus *Cactoblastis.* It was introduced into Australia in June, 1925, and has already done marvelous work in the destruction of the prickly pear. About sixty million eggs have recently been distributed, and from now on it is expected to distribute at least one hundred million a year, as long as may appear necessary. The one fear is that some native or introduced insect may take to preying on *Cactoblastis* in such numbers as to nullify its work, but so far nothing of the kind has happened. The genus *Cactoblastis* has one other species, described by Dyar, which occurs at Mendoza, Argentina, and has not been imported. Last year Dyar named a third (*D. leithella*) from Curaçao in the Dutch West Indies, the distinction resting wholly on the habits and appearance of the larva, as described by the collector, Mr. Leith F. Hitchcock.

The intensive study of *Opuntia* insects has brought out a number of facts of great biological interest, and suggests the desirability of promoting other studies of the same type, whether of immediate economic significance or not. Thus the whole subject of the cochineal insects (*Dactylopius*) has taken on a new aspect. Having paid much attention to these insects in former years, I can testify that morphologically the several forms are very much alike, so that the number of species has been in doubt. But Dodd and

his colleagues find that their habits are different. The destruction of the prickly pears in the course of a few months by the species called *Dactylopius tomentosus* has been amazing; the more so, because in its native country this species never works such havoc. But it is found that different cochineals infest different species of *Opuntia*. The Indian cochineal (really American, but imported into India and Ceylon) attacks *Opuntia monacantha*, but refuses all other species of these cacti. The cochineal common in our southwest, *Dactylopius confusus*, similarly restricts itself to certain species, though not to a single one. Still another sort, *D. newsteadi*, is as efficient against *Opuntia imbricata* as *D. tomentosus* is against *O. inermis* and *O. stricta*, but it will not attack the other kinds. Thus we see how necessary it is, for the purposes of economic entomology, to critically distinguish between closely allied insects. The species of cochineal may possibly prove to be quite numerous, but at present we can distinguish the following:

(1) *Dactylopius coccus* Costa (*signoreti* Ckll.). The commercial cochineal.

(2) *Dactylopius opuntiae* (Lichtenstein in litt., Ckll.) is probably the more correct name for what is called *D. tomentosus* (Lamarck). We know exactly what it is, and in view of the now known diversity of types, it is probably impossible to say which Lamarck had or referred to.

(3) *Dactylopius confusus* (Ckll.), common in the Rocky Mountains of Colorado, and New Mexico, and in other southwestern states. The material from Ceylon, South Africa and Florida ascribed to *D. confusus* may not all pertain to this species.

(4) *Dactylopius greenii* n.n. (*Coccus confusus capensis* Green, 1912, not *Coccus capensis* L., 1766). Described from South Africa, but of American origin, and thus inappropriately called *capensis*. It occurs on *Opuntia monacantha*, and has been imported into Australia.

(5) *Dactylopius ceylonicus* (Green, 1896) (*indicus* Green, 1908). Also carried to Australia, and very effective against *O. monacantha*. The names applied to it are inappropriate, since the species originated in America, and is at home in Argentina. It has been very efficient against *O. monacantha* in India and Ceylon, but the related *O. dillenii* is practically immune. The name *ceylonicus* (*Coccus cacti* var. *ceylonicus*) was first published, and the brief description given prevents it from being a nomen nudum. Also, the name *Dactylopius indicus* is preoccupied.

(6) *Dactylopius newsteadi* (Ckll.), described from Arizona, and now carried to Australia. The locality, Colorado, given in the Fernald catalogue, is an error.

(7) *Dactylopius argentinus* Dominguez, 1907. Argentina, on *Opuntia ficus-indica* and *O. aurantiaca*. Whether this is valid, I do not know. *D. opuntiae* will not attack these species.

Another very interesting observation relates to the red-spider (really a mite) of the prickly pear, *Tetranychus opuntiae* Banks. This has been considered synonymous with the common greenhouse species, on morphological grounds, but its habits indicate otherwise. It is very efficient against *Opuntia inermis*, but can not be transferred to the plants infested by the common red-spider. Its operations induce the cactus to form a corky layer, analogous to gall-formation, and it is very remarkable that this process, once started, goes on, beyond the actual location of the mites, until it covers and smothers the joint. Mr. Dodd records (1927) that "although quite different in its mode of attack, the red spider is equally as important as the cochineal; together these two insects form a harmonious combine by which there is every reason to believe that the dense scrub areas of *O. inermis* will be eradicated." The prickly pear mite was described from Arizona, but the Australian material was obtained from Texas.

T. D. A. COCKERELL

UNIVERSITY OF COLORADO,
JANUARY 23, 1929

THE SMALLEST LIVING VERTEBRATE

UNQUESTIONABLY the smallest fish and the most diminutive of all vertebrates is a Philippine goby discovered by the writer and described in his volume entitled "Gobies of the Philippines and China Sea."

In 1902 Hugh M. Smith described a minute goby from Lake Buhi, Luzon, under the name of *Mistichthys luzonensis*. This species when full grown has an average length of 12.5 mm, males varying from slightly less than 10 to 13.5 mm in length; ripe females ranging from a little over 11 to 14 mm in length. This tiny fish, known as *sinarapan* in the Bikol language, occurs only in Lake Buhi, where it is exceedingly abundant and is caught in large numbers for food. It is easily the smallest commercial fish.

Tiny as *sinarapan* are, they are not nearly so small as a fish collected in the tidal creeks about Malabon, a town a few miles north of Manila. This species, which I named *Pandaka pygmaea*, is known from only seventy-five specimens. Adult males range from 7.5 to 9 mm in length, and females distended with eggs are from 10 to 11 mm long.

Compared to all other Lilliputian fish from various parts of the world both *Mistichthys luzonensis* and *Pandaka pygmaea* are very much smaller, even when not so very much shorter. They are both slender fishes and in life are colorless and so nearly transparent that only their large black eyes are visible. Conditions in the Philippines and especially in Luzon have produced an extraordinary variety of gobies,

but it is remarkable that the island of Luzon should have produced the two smallest species of fish in the world, both gobies.

ALBERT W. HERRE

THE HYDROGEN-ION CONCENTRATION OF THE BLOOD IN CANCER

BOTH the lay and the scientific press have recently given considerable publicity to the low hydrogen-ion concentration of the blood in cancer. This is chiefly due to Dr. Ellice Macdonald, who mentions the subject in an address published in SCIENCE of the 15th *instant*. He seems to credit the discovery to Reding, of Brussels, making no mention of Dr. Maude Menken. Dr. Menken first observed the low hydrogen-ion concentration of the serum in cancerous patients and published her results in the *Journal of Cancer Research*, vol. 2, 1917.

H. O. NOLAN

ISOGRAM VS. ISONTIC

UNDER the title "Isontic?"[1] Lane voiced the need for a generic term applicable to the whole class of iso- and equi-lines and surfaces. Comment on this paper by Miller led to correspondence that we hope may be of sufficient interest to the readers of SCIENCE to merit a brief summary.

"Isogram" was proposed for the same purpose by Francis Galton in *Nature* (40: 651, 1889) and it has found acceptance by others.[2]

The expression "connecting points of," used by Galton and by Lane in defining isotherm and other isograms, lacks uniqueness, since lines not themselves isotherms can connect points of equal temperature. We recommend in lieu of it, the phrase "consists of" *e.g.*, isotherm, a line (or by extension surface) consisting of (extending, traced or drawn through) points of equal temperature. An isogram would be a line (or surface) all points in which are equal in some one respect.

ALFRED C. LANE

TUFTS COLLEGE

ERIC R. MILLER

UNIVERSITY OF WISCONSIN

QUOTATIONS

A DESCENDANT OF JOHN HUNTER

ON February 11 there died in the Sisterhood Home, St. Hilda's, Shirland Road, Paddington, where she chose to spend the evening of a life spent in well-doing, Miss Helen Hunter-Baillie, the senior representative of the Hunter family and a woman of exceptional ability. She was eighty-five years of age, and could read without glasses and retained her freshness of mind to the end. On the death of her sole surviving brother in 1895 she became "laird" of Long Calderwood—the birthplace of William and John Hunter, and also of Dorothea Hunter, who became the mother of Dr. Matthew Baillie, physician, and Joanna Baillie, poetess. The excellent state of preservation of the old farmhouse at Long Calderwood is owing to Miss Hunter-Baillie's care and vigilance, and to the keen and intelligent interest she took in all that pertains to the men who did so much to mould the progress of medicine in this country during the eighteenth century. Her father, Mr. William Hunter-Baillie, was the only surviving son of Dr. Matthew Baillie, and was born in 1797 within the school which Dr. William Hunter built in Great Windmill Street—a building which still serves as an annex for the Lyric Theater. He was educated at Westminster School and Balliol College, Oxford, was called to the Bar, and, although he never practised, did act for a time as marshal to his distinguished uncle Lord Denman. He inherited a fortune from his father, devoted himself to literature, society and good works, and imparted much of his tastes and learning to his daughter, Miss Helen Hunter-Baillie. He lived for the greater part of his life at 96, Harley Street, and died in 1894 at the age of ninety-seven, and in his home Miss Hunter-Baillie met the leaders of literature and science of the nineteenth century. She wrote in her retreat a small typewritten volume of valuable reminiscences, a copy of which is preserved in the library of the Royal College of Surgeons of England. . . . At an early date she began to collect all old letters which had come down in the family from the Hunters, Baillies, Jenners, Barons, Denmans, Crofts; and these she arranged and catalogued and bound in seven volumes, and presented this valuable collection of documents to the library of the Royal College of Surgeons. To Miss Hunter-Baillie and to her brother, Captain William Hunter-Baillie, the Royal Colleges are indebted for many valuable portraits and busts of the Hunters, Baillies and also of Jenner. At the Hunterian Oration, given biennially in the theater of the Royal College of Surgeons, she was always a welcome guest, and had assigned to her a place of honor, which she well became. Students of the lineaments of John Hunter saw in her face, head, body, deportment and inquiring mind much which reminded them of those of her grand uncle. She was keenly interested in the Hunterian collections preserved in the museum and

[1] SCIENCE, 68: 37, 1928.

[2] Talman, *Sci. Am. Supp.*, Nov. 12, 1910, and *Monthly Weather Review*, 43: 195, 1915.

library of the college. Miss Hunter-Baillie is now represented by the children of her two younger sisters —Henrietta, who married the Reverend J. Maconechy, of All Saints', Norfolk Square, and Agnes, who married the Reverend R. B. Oliver, of Whitwell, Isle of Wight. In the Oliver family she had two nephews—the Reverend B. L. Baillie Oliver and the late Matthew William Baillie Oliver, F.R.C.S., whose early death three years ago was a great blow to her. These two nephews have left no descendants. A daughter of Mrs. Maconechy became the wife of Dr. T. Battersby Jobson; of that marriage there are four children. Thus, of the ten children born to John Hunter and his wife Agnes Paul, in the farmhouse of Long Calderwood two centuries ago, there are now only eleven lineal living descendants, representing the fifth and sixth generations. Although these are all that are descended from the Calderwood branch of Hunters, there is another line of Hunters which traces its origin to a senior brother of the John Hunter who became laird of Long Calderwood. The representative of this senior branch is Colonel C. S. Hunter, D.S.O.—*The British Medical Journal.*

SPECIAL CORRESPONDENCE

THE PUGET SOUND BIOLOGICAL STATION

MARINE biological stations meet a definite need by affording professors and students of institutions far from the ocean an opportunity to study the marine flora and fauna. The famous station at Naples has added immensely to our knowledge of the flora and fauna of the Mediterranean; and the station at Woods Hole, Mass., has done similar service for our Atlantic forms; and equally valuable has been the annual assembling of investigators whose discussions and personal acquaintance have enabled many of them to accomplish what they could not have done in the seclusion of their own laboratories.

The Puget Sound Biological Station is comparatively new, but it is offering increasing facilities to students and investigators. It is situated on San Juan Island in Puget Sound, between Vancouver and Seattle, and is maintained by the University of Washington under the efficient direction of Professor T. C. Frye. The coast line is ideal and there is a wonderful display of plant and animal life. Immense brown algae a hundred feet long can be seen from the laboratory windows; and, at night, every stroke of an oar brings a phosphorescent flash from flagellates or jelly fish. Land flora is equally rich, with eight genera of Gymnosperms within botanizing reach.

As early as 1895, biologists were becoming impressed by the wealth of material and small classes were held at various places. In 1903, Professor Trevor Kincaid urged the establishment of a permanent station and the next year, with Professor T. C. Frye, he spent six weeks at Friday Harbor, a small town less than two miles from the present station. Their laboratory was a table three and one half by ten feet, under a Douglas fir tree. There was no class work; but in 1906 they were given the use of an abandoned fish cannery and they offered one course in zoology and one in botany. The cannery was soon sold, but an enterprising citizen of Friday Harbor gave them four acres of land and the university built a laboratory and dining-hall. For a time, Professor Kincaid was director, but since 1913 Professor Frye has been the director and the station has continued to develop, with increasing laboratory space and increasing facilities for research. In 1922 the unused military reserve of 484 acres was secured and permanent buildings were erected. There are now five laboratories for class work, one for research, a stock room and a dining-room, besides cottages for the director and curator. The students and investigators live in comfortable army tents. Library facilities are increasing.

The station has a steamer which makes almost daily trips, with no additional expense to the student, so that there is an opportunity to visit almost every island in Puget Sound. There is a large dredge which brings up deep-sea life in perfect condition. Besides, the station is near the heart of the salmon industry, so that forms which might not be secured in any other way can be gotten from the immense fish traps.

While courses are offered only during the summer, arrangements are being made to keep the station open for research throughout the year.

Teachers and investigators are brought in from all parts of the country and even from abroad. Specialists in various fields have catalogued material, so that identification of much of the flora and fauna is well under way. The following partial list of men who have been at the station as teachers or investigators will give some idea of the work:

J. M. Aldrich, U. S. Natural History Museum, insects; Rupert S. Anderson, Columbia University, phosphorescence; Charles E. Bessey, plant morphology; C. M. Child, University of Chicago, animal senescence; Bruce Fink, Miami University, lichens; E. M. Griffin, Reed College, corals; H. H. Gran, Oslo, Norway, diatoms; N. L. Gardner, University of California, marine algae; Harold Kylin, University of Lund, Sweden, marine algae; Trevor Kincaid, University of Washington, oysters; Wm. Kellogg, Williams College, clams; W. C. L. Muenscher, Cornell University, plant diseases; E. B. Powers, University of Tennessee, animal ecology; V. E. Shelford, University of Illinois, animal ecology; E. C. Starks,

Stanford University, fishes; Josephine Tilden, University of Minnesota, algae; Elda Walker, University of Nebraska, plant morphology; R. B. Wylie, University of Iowa, plant morphology; Charles Zeleny, University of Illinois, embryology.

In 1928 the total number of students was 132, of which forty-two were graduate students doing class work and twenty were graduate students doing research. Besides, there were six teachers doing research.

Expenses are light, but work is strenuous. There are no tourists, even for a single night. Play is encouraged, so that at the end of nine busy weeks one feels that he has had a vacation while he was teaching or doing research.

CHARLES J. CHAMBERLAIN
UNIVERSITY OF CHICAGO

THE AMERICAN MEDICAL ASSOCIATION OF VIENNA

THERE exists in Vienna the American Medical Association of Vienna, which is a well-developed organization founded for the purpose of facilitating post-graduate medical work for English-speaking physicians. All the English medical courses given under the auspices of the University of Vienna are administered through this organization.

Many Americans come to Vienna for post-graduate medical work and apparently profit by so doing. Many others write to professors and business organizations asking for information, indicating a lack of knowledge of our organization.

We have an annual membership of nearly 1,000 new doctors, who come from various parts of the world, and who obtain their work through our organization. It is thoroughly well organized, with four secretaries to orient new members and assist them in obtaining medical courses, housing, money matters, shopping, sightseeing, etc.

For further information, address The American Medical Association of Vienna, Vienna VIII. Alserstrasse 9, Austria.

RALPH A. REYNOLDS

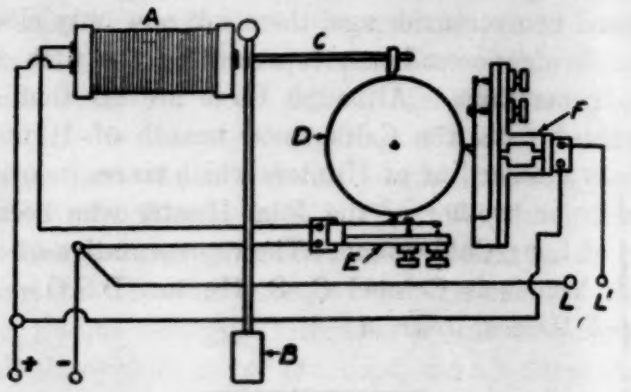
SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN IMPROVED CHRONOGRAPH

A VAST number of instructors in laboratories of experimental physiology have had difficulties with time clocks. For a number of years a Harvard chronograph has been used in the department of physiology and pharmacology of the Michigan State Laboratory. Because of the conditions imposed the results were not at all satisfactory.

Due to a reorganization of the laboratory courses in 1925–26 whereby all students were required to perform a regular series of physiological experiments, the load upon the clock and the consequent annoyances resulting from its malfunctioning became unbearable. In casting about for a remedy the difficulties were casually stated to Mr. Phippeny, at that time operator of WKAR. After making a careful survey of the situation Mr. Phippeny stated that the pendulum-driven Harvard chronograph should satisfactorily meet our conditions provided certain changes were made in the wiring.

The large pendulum-driving magnet (Figure 1 *A*)



was rewound with No. 30 B & S enameled copper wire, and the connecting wires on the chronograph were rearranged in such a manner (see Figure 1) that the pendulum is driven by a shunt from the main source of current. In order to meet our needs for time magnets at fifteen or twenty desks a 24-volt storage battery and a rectifier were installed, and the bobbins of the Harvard signal magnets were rewound with No. 38 B & S enameled copper wire.

Current is supplied to the desk from a line of about 100 feet attached at *L L'* and enclosed in overhead conduits. Readily removable drop cords of proper length extend to the desks. When not in use these cords are removed and stored. When the conduit was installed three wires were placed therein so that two different time intervals would be obtainable at all desks, and a special three-prong plug was used upon the drop cords. To allow for this an extra time bar takeoff *F* was to be placed upon the proper support and suitable connections made. Although this has not been carried to completion the special three-point plug has frequently prevented students from plugging into the 110-volt current which is also carried about the laboratory in conduits.

During the time this chronograph has been in operation there have been two difficulties with which we have had to deal. The small storage batteries originally installed were found to be inadequate and it was necessary to charge them continuously when all the desks were occupied. The variations caused

by changes in the load necessitated frequent adjustments of the platinum-tipped screws of *E* and *F*. More recently since two large 12-volt storage batteries have been installed there has been little difficulty in keeping the batteries charged, but when fully charged they are capable of overheating and burning the spring of the time bar takeoff *F* if there is a short circuit in the line. Such an accident occasionally happens when one of the students, who is inexperienced in affairs electrical, attaches both wires from the time clock to the frame of the signal magnet, *i.e.*, one to the regular binding post and the other to the screw intended for adjusting the writing point. It is expected that this difficulty will be overcome by the installation of a suitable fuse.

ALVAH R. MCLAUGHLIN
UNIVERSITY OF WYOMING

METHODS OF COLLECTING CARCASSES

THE conducting of a zoological field problem which requires the collecting of bird and mammal carcasses may represent an almost unjustifiable demand in the amount of time and effort required. The matter of securing a quantity of material of such species as fox, mink, weasel and owl (all forms of more or less wide and elusive range habits) and the bringing into the laboratory of the material needed for investigation of such questions as can be determined only by the compilation of data secured from specimens, may most efficiently be accomplished, according to my experience, by employing the help of sportsmen, taxidermists and raw-fur dealers. There are several distinct advantages in securing the material in this way. First, it is a practical impossibility for one worker in a limited time to take in the field or to trap any of our local carnivora, for example, in sufficient numbers to furnish adequate data. Second, something may be contributed to the spirit of conservation if the carcasses of animals secured by these people, otherwise wasted, can be utilized for a laboratory analysis of certain ecological factors. Third, some knowledge as well as sympathy and enthusiasm concerning the biology and conservation of game may be shared by the laymen and the scientific investigator by such cooperative efforts in collecting the necessary material. Fourth, local history of a species and information regarding its local habits as gleaned from sportsmen and farmers, while not always reliable, are often sufficiently accurate to be of material value to the investigator.

In order to enlist the greatest number in getting material the worker must approach the sportsmen and dealers, and present his problem in such a manner as to gain their respect for his project. After that the best technique I have developed in two years of experimenting is to distribute a series of large cans, buckets or kegs—one- to ten-gallon containers—each fitted with a tight cover and tagged with a proper label. Each receptacle should contain a 5 per cent. solution of formalin. Such a container delivered to the sportsman, taxidermist or raw-fur dealer enables him, with the least amount of trouble to himself, to preserve, merely by dropping into this container, the carcasses which he has at hand—a most important consideration for the investigator who wishes to secure a quantity of material.

The first collecting of this kind made by the author consisted of the stomachs and entrails of ruffed grouse. Early in this work it was noted that a rather low per cent. of birds estimated to have been killed was being contributed by cooperating sportsmen. To meet this condition a greater number of formalin jars were distributed, which allowed gunners to save a greater quantity of material without fearing that they were incriminating themselves before the law, in respect to the bag limits on grouse, or shadowing their self-respect in consideration of the growing scarcity of this bird.

Such collecting operations, according to my experience, never increase the kill in a community, but may actually lessen it since the sportsmen know that one phase of the study is that of evaluating the effect of the hunters' kill upon the maintenance of the species. But their knowledge of that aim of the study may spell failure in the securing of any appreciable percentage of the numbers killed during the open season, unless the collector has gained the confidence and respect of these people and is careful to spread the feeling that any contributing effort on their part is valued by him and that the success of his undertaking is of fully as much importance to them as to him.

To secure any field data of value with the individual specimens collected is, I have found, always a difficult matter. Sometimes to insist that labels be attached to the individual specimens results in the falling off of the amount of material secured. Fur dealers and taxidermists from whom I have received the greatest cooperation do not have at hand any exact information regarding many specimens which come into their shop. Many others do not like to be questioned thus closely regarding their field operations.

Two kinds of labels for attaching to specimens have been used with some success. Mr. Perry J. Nickerson, taxidermist at Syracuse, New York, has instituted a very practical method for the use of cooperating taxidermists who book a record of specimens as they come into the shop. He uses a small numbered aluminum tag with a wire attachment. When a specimen is brought into the shop the carcass

of which is to be thrown into the formalin jar, one of these tags is attached to a leg and its number recorded with the original entry in the record book. From this record the locality from which the specimen came and its species can be determined. Many times it pays to seek further information concerning a particular specimen by field contact with the man who killed it. Mr. Joseph Buff, raw-fur dealer in Syracuse, who collected for me a generous number of weasel and mink carcasses, used a small shipping tag on which information was written with a soft pencil and then tied to the carcass before placing it in formalin. This method requires a little more time but is of greatest help to the investigator.

R. A. JOHNSON

SPECIAL ARTICLES

THE FUNCTION OF THE AIR SACS IN HOLOPNEUSTIC INSECTS

AIR sacs are present in probably all of the flying and in many of the non-flying insects. In the past, two different functions have been ascribed to these structures in holopneustic forms, but the evidence offered has been far from convincing. Newport[1] observed that the number and volume of the air sacs were correlated with the powers of flight of the insect, and was led to the belief that they serve for buoyancy during flight by lessening the specific gravity of the body. Such a function is manifestly impossible, but is still held at the present time. A late text-book of entomology[2] states (p. 119):

> As the air sacs lessen the specific gravity of the insect they probably aid in flight, as filling the lungs with air makes it easier for a man to float in water; in each case there is a greater volume for the same weight.

Another and more logical view is that the air sacs are merely reservoirs or stores for air, especially well developed in those forms which consume a great deal of oxygen in flight or active movement. There are several reasons for considering such a simple explanation inadequate. There would seem to be no advantage to an insect in having air reservoirs within the body when the whole atmosphere is a reservoir just a few millimeters away through the open spiracles. The air in the sacs, unless constantly renewed, could not serve as a store for very long, since less than 20 per cent. of it is oxygen, and the total volume of the sacs is small as compared with the volume of oxygen the animal uses in an hour. There would also seem to be little advantage in having a great number of small sacs rather than a few large ones.

The explanation suggested here avoids these difficulties and accounts for the parallel development with the powers of flight and activity. This explanation is that the function of the air sacs is chiefly mechanical in allowing a considerable volume of air to be inhaled and exhaled, thereby causing a ventilation of the larger tracheal trunks. In so far as the mechanics of respiration is concerned, the insect could be compared in several respects with the bird or mammal. The active expansion of the abdomen of the insect is analogous to the increase in size of the body cavity in the bird or of the thoracic cavity in the mammal. During the expansion of the abdomen the hemocoele of the insect becomes larger and the intracoelomic pressure must decrease and become less than atmospheric. The outside air, having free access to the tracheal system through the spiracles, will then cause the thin-walled and elastic air sacs, *wherever they are located,* to dilate and fill. During expiration the abdomen is compressed and made smaller, the intracoelomic pressure becomes greater than atmospheric, and this increased pressure, transmitted by the blood to all parts of the body, will cause the air sacs to collapse and empty. The greater the total capacity of the air sacs the greater must be the possible ventilation at each respiration, within the limits of expansion of the abdomen.

The walls of the ordinary tracheae contain a spiral chitinous thickening, and offer a considerable resistance to pressure tending to collapse or distend them. The cavities of the insect's body have no connection with the lumina of the tracheae. Hence, in an insect possessing no air sacs or such distensible structures, both the inspiration and expiration of air would be impossible. The ventilation of the tracheal trunks could be accomplished only by the mechanism of diffusion.

The number of air sacs in an insect may be surprisingly great. Landois[3] stated that there are about 550 in the male of *Melolontha vulgaris*. Packard[4] counted fifty-three sacs in the head alone of *Melanoplus femur-rubrum*. According to Newport[1] there are air sacs even in the mandibles of the stag beetle. In some of the very active insects the sacs form a veritable complex in the thorax and abdomen. It is noteworthy that many of the sacs arise from the smaller tracheal branches at a considerable distance from any spiracle. Even the largest ones usually do not open immediately from the spiracular trunks, but from the transverse or longitudinal trunks. Neither are the air sacs blind pockets at the ends of tracheal tubes, but

[1] *Trans. Linn. Soc.*, 20: 419, 1851.

[2] Comstock, "An Introduction to Entomology," Ithaca, N. Y., 1925.

[3] *Zeitschr. f. wiss. Zool.*, 17: 105, 1867.

[4] First Report U. S. Entomol. Comm., p. 269, Washington, 1878.

usually have many efferent branches to adjacent tissues which are short as compared with the total length of the tracheal tree.

If the above view of the function of the air sacs is correct there would be an enormous advantage in having such a great number of small sacs scattered throughout the body, rather than a few large ones. Each sac would serve to ventilate the section of tracheal tube between it and the nearest open spiracle. The agitation given to the column of air in the tortuous tracheae would be very effective in aiding the diffusion of gases. Krogh[5] and Winterstein[6] have expressed doubts as to the possibility of diffusion alone through the long, narrow tracheal tubes being able to supply an adequate amount of oxygen to the tissues, especially during activity. Krogh has further shown experimentally in a series of ingenious experiments that diffusion alone is sufficient for an adequate gas exchange in the great majority of larvae, all pupae, and in the smaller and more lethargic adult insects. In the larger and more active forms with well-developed powers of flight, however, diffusion alone must be inadequate. If the function of the air sacs outlined above is correct, the difficulty disappears. For the comparatively short distances between the air sacs and the tissues the process of diffusion would supply a sufficient amount of oxygen, even to the organs of the head which are farthest removed from any spiracles. The parallel development of the air-sac system with the powers of flight would indicate the efficiency of the mechanism for supplying an adequate gas exchange for such an oxygen-consuming activity.

MILTON O. LEE

HARVARD UNIVERSITY

COMPOSITION OF BONE, VII. EQUILIBRATION OF SERUM SOLUTIONS WITH $CaHPO_4$

IT is generally taken for granted that bone consists chiefly of $Ca_3(PO_4)_2$ and that when calcium phosphate is deposited in the bones it is in the form of this compound, tricalcium phosphate. There have been several notable attempts to account for the deposition of tricalcium phosphate on the basis of solubility product considerations. Holt, La Mer and Chown[1] interpreted their experiments as showing that "serum is normally supersaturated with tertiary calcium phosphate to the extent of more than 200 per cent." Not only normal serum is supersaturated but also "Even in active rickets this ion product is greater than that required to precipitate $Ca_3(PO_4)_2$," according to Holt.[2] Sendroy and Hastings[3] obtained similar experimental data with $Ca_3(PO_4)_2$, but concluded that supersaturation can not be the sole explanation "for the apparently abnormal amounts of calcium in serum," and that the data indicate "that calcium exists in serum in abnormal amounts bound to some substance or substances which hold it in solution in unionized form."

In a previous communication[4] we presented evidence which indicated that serum does not contain abnormal amounts of calcium and that serum and inorganic serum solutions are not supersaturated but are undersaturated. Furthermore, the important substance appears to be $CaHPO_4$ and not $Ca_3(PO_4)_2$. Our calculations showed that in inorganic serum solutions with $Ca \times P$ products less than 30, $[Ca^{++}] \times [HPO_4'']$ is less than the solubility product of $CaHPO_4$, and that in solutions with $Ca \times P$ products ranging from 40 to 60, $[Ca^{++}] \times [HPO_4'']$ is very nearly equal to the solubility product of $CaHPO_4$.

This value for $K'_{s.p.}CaHPO_4$, the solubility product of $CaHPO_4$, was obtained by extrapolation from data in the literature. The present paper is a preliminary communication giving the value of $K'_{s.p.}CaHPO_4$ obtained experimentally at the ionic strength of serum.

An inorganic serum solution was made up containing 8 mg per cent. calcium and 3 mg per cent. phosphorus. Aliquots of this solution were equilibrated at room temperature with an excess of crystalline $CaHPO_4$. It was found that equilibrium was obtained after shaking for only one hour, and that the equilibrium was independent of the amount of the solid phase. The concentrations both of calcium and of phosphorus were *greater* at equilibrium than in the initial solution. Fifteen experiments were performed at room temperature; the mean value obtained for $K'_{s.p.}CaHPO_4$ was 3.2×10^{-6}. Twenty similar experiments were performed at 38°; the mean value obtained for $K'_{s.p.}CaHPO_4$ at 38° was 3.4×10^{-6}.

In making these inorganic serum solutions, the initial $Ca \times P$ product was varied from zero to 60; some contained high calcium and low phosphorus concentrations; others contained the reverse. After equilibration, the ion product obtained in all these solutions was identical. Equilibration with $CaHPO_4$ caused an *increase* in the concentration of calcium or

[5] *Pfl. Arch. f. d. ges. Physiol.*, 179: 113, 1920.

[6] "Hdb. d. vergl. Physiol.," 1, p. 111, Jena, 1921.

[1] L. Emmett Holt, Jr., Victor K. La Mer and H. Bruce Chown, *Jour. Biol. Chem.*, 64: 509, 567, 1925.

[2] L. Emmett Holt, Jr., *Jour. Biol. Chem.*, 64: 579, 1925.

[3] Julius Sendroy, Jr., and A. Baird Hastings, *Jour. Biol. Chem.*, 71: 783, 797, 1927.

[4] M. J. Shear and Benjamin Kramer, *Jour. Biol. Chem.*, 79: 125, 1928.

of phosphorus, or of both, in all solutions with Ca × P products less than 45. In all these solutions, the ion product after equilibration was greater than the initial ion product; such solutions are therefore *undersaturated.* Inorganic serum solutions with Ca × P products in the neighborhood of 50 are saturated with respect to $CaHPO_4$ at a pH of 7.4, since equilibration with $CaHPO_4$ causes no change in the ion product $[Ca^{++}] \times [HPO_4'']$.

Howland and Kramer[5] showed that in active rickets the serum Ca × P product was always less than 35, whether the calcium was high and the phosphorus was low, or whether the calcium was low and the phosphorus was high. The ion product $[Ca^{++}] \times [HPO_4'']$ in a serum with a given calcium and phosphorous content can not be greater than the ion product in an inorganic serum solution with the same calcium and phosphorus content. If it is at all different, it must be less in serum since part of the calcium appears to be bound to protein. Inorganic serum solutions with Ca × P products of 35 or less are definitely undersaturated with respect to $CaHPO_4$; ricketic serum must therefore also be undersaturated with respect to this substance.

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ACTION OF HYDROGEN SULFIDE ON THE PROTOPLASM OF AMOEBA PROTEUS

IT has been reported by various investigators [1, 2, 3, 4, 5] that certain weak acids, namely, CO_2, HCN and H_2S, enter living cells largely in the molecular form and probably exert their toxic effect by intracellular ionization. It has recently been reported, however, that microinjections of CO_2[6] and HCN[7] into amoebae do not irreversibly injure the cell unless the dosage is so large that it destroys the surface membrane. On the other hand, amoebae immersed in the same solutions die very quickly. Therefore, it appears that the physiological action of CO_2 and HCN is largely a surface one. Since the toxicity of HCN and CO_2 seems to be due to their effect on the cell membrane, it was thought desirable to ascertain if H_2S exerts its effect on the cell membrane. The solutions of H_2S used were saturated, three quarters, one half and one quarter saturated. The pH values of the solutions varied from 5.0 to 5.4, depending upon the concentration of sulfide. Some amoebae were immersed in the sulfide solutions and others were injected with the same solutions by means of Chambers' micromanipulator. The organisms were studied under direct and indirect illuminated microscopes. The rate of Brownian movement of the microparticles was used as an index of the viscosity of the protoplasm.

Immersion Experiments: When amoebae are immersed in aqueous solutions of hydrogen sulfide, the viscosity of the protoplasm is increased. The animals retract their pseudopodia and assume a spherical form. The granular portion of the protoplasm collects into a semi-gelated mass near one end of the cell, and the remainder of the organism is composed of a hyaline material. Finally, the cell membrane ruptures in one or more places and the hyaline fluid escapes into but does not mix with the surrounding solution. The granuloplasm distintegrates and the individual particles scatter in the sulfide solution.

Injection Experiments: Aqueous solutions of H_2S were injected into amoebae in amounts equal to nearly one half the volume of the cell. The sulfide quickly diffuses throughout the protoplasm, producing a reversible increase in viscosity. The organisms completely recover within one to two hours.

When amoebae are injected with H_2S and the animals immediately immersed in the sulfide solution, the animals react in a similar manner to the uninjected individuals in the same sulfide solution, *i.e.*, a slight swelling of the protoplasm and disintegration of the cell. The injected amoebae do not die any sooner after immersion than the uninjected animals.

Tearing the Cell Membrane: If amoebae are immersed in solutions of hydrogen sulfide and the cell membrane torn with microdissection needles, a new membrane is formed over the injured surface which indicates that the internal protoplasm has not been greatly injured.

Summary: Experiments on immersion and injection indicate that for amoebae the toxicity of hydrogen sulfide is largely due to its action on the surface membrane and that the internal protoplasm is not irreversibly injured.

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